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DEPARTMENT OF THE ARMY FIELD MANUAL

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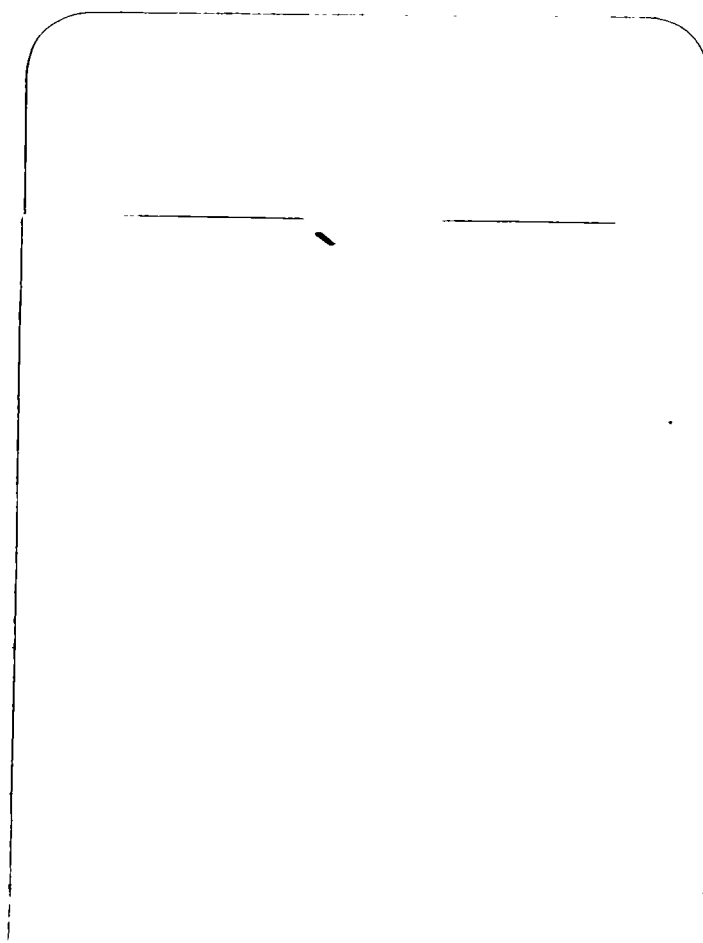
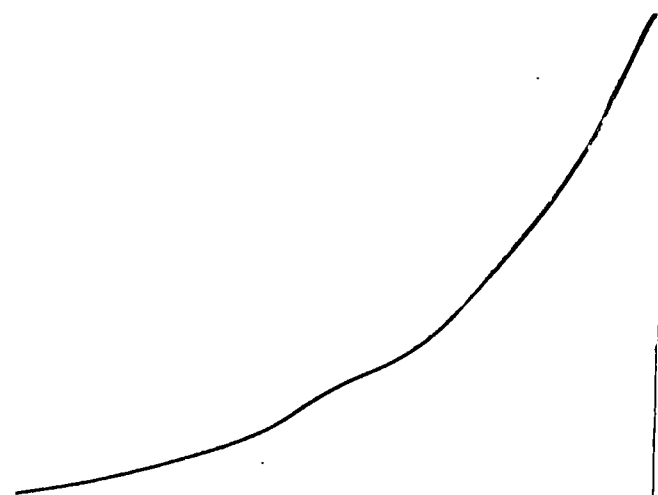
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HEADQUARTERS, DEPARTMENT OF THE ARMY

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FIELD MANUAL

No. 5-35

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., 15 April 1971

ENGINEERS' REFERENCE AND LOGISTICAL DATA

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CHAPTER 1

INTRODUCTION

1-1. Purpose and Scope

This manual is intended to provide engineer and other military personnel with a compilation of data for use in planning of engineer activities. It includes data pertaining to engineer troops, equipment, construction materials, and to all types of engineer troop functions including soils, drainage, roads, railroads, bridges, port construction, airfields, heliports, POL distribution, barrier and denial operations, fortifications and protective structures, camouflage, general construction, and mapping. It also contains some frequently used design formulas, miscellaneous physical and mathematical data and conversion tables.

1-2. Relation to Other Manuals

Material in this manual has been drawn from many Department of the Army Field Manuals,

Technical Manuals, Supply Catalogs and commercial publications. References are made to the source of the material throughout the text, and in Appendix A. Referenced texts will contain more detailed information and should be referred to in final planning for any major construction project or operation.

1-3. Changes

Users of this manual are encouraged to submit recommended changes and comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons will be provided for each comment to insure understanding and complete evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications) and forwarded direct to the Commandant, U.S. Army Engineer School, Fort Belvoir, Virginia 22060.



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CHAPTER 2

ENGINEER TROOPS

2-1. Introduction

FM 5-1 sets forth the mission, assignments, capabilities, organization, and normal employment of all engineer troop units. The TOE's for these units give further personnel and equipment details.

2-2. Strength of Engineer Units

Tables 2-1 and 2-2 give the basic data for

engineer troop units and engineer teams. Strength figures given in these tables are for units authorized strength level 1, with type B strength levels, where applicable, shown in parenthesis below. Strength level 2 is approximately 90% of level 1, and level 3 is approximately 80% of level 1. Actual authorized strengths for levels 2 and 3, and definitions of the different unit categories and types, appear in FM 5-1 and the appropriate TOE's.

Table 2-1. Engineer Troop Units

TOE No.	Unit	Authorized strength				Normal assignment	Weight (ST)	Mission
		OFF	WO	EM	Total			
5-25G	Engineer Battalion, Airborne Division.	32	2	544	578	Organic to airborne division.	882.8	To increase the combat effectiveness of the airborne division and carry out airborne infantry combat missions when required.
5-26G	Headquarters and Headquarters Company, Engineer Battalion, Airborne Division.	17	2	166	185	1 per battalion -----	505.1	Provides engineer special staff for division and command and staff for the battalion. Provides alternate CP, administration, operations control, communications, reconnaissance and engineer intelligence, supply, organization maintenance support, supplemental engineer and ordnance equipment, and unit level medical service for the engineer battalion. Provides potable water for the division and plans for employment of atomic demolition munitions when appropriate teams are attached.
5-27G	Engineer Company, Engineer Battalion, Airborne Division.	5	0	126	131	3 per battalion -----	125.9	Is operating component of engineer battalion and carries out airborne infantry combat missions when required.
5-35G	Engineer Combat Battalion, Army or Corps.	37	4	795	836	To corps or army with normal attachment to an engineer combat group.	2413.7	To increase combat effectiveness of corps and army, to reinforce divisional engineer units, and to perform infantry combat missions when required.
5-36G	Headquarters and Headquarters Company, Engineer Combat Battalion, Army or Corps.	17	4	203	224	1 per battalion -----	708.6	To provide an alternate CP, administration, operations control, communications, reconnaissance and engineer intelligence, supply, organizational maintenance support, supplemental engineer and ordnance construction equipment, and medical service for the battalion. Provides potable water for corps or army. Provides planning, preparation and firing of atomic demolition munitions.
5-37G	Engineer Combat Company, Engineer Combat Battalion, Army or Corps.	5	0	148	153	4 per battalion -----	426.3	Performs engineer work in support of the field army or corps and carries out infantry combat missions when required.
5-38G	Engineer Combat Company, U.S. Army Missile Command, Air Transportable.	5	1	186	192	1 per missile command.	374.6	Performs engineer work in support of the army missile command.
5-52G	Headquarters and Headquarters Company, Engineer Combat	16	13	81	110	1 per 4 to 7 engineer battalions.	162.7	To command assigned or attached units. To plan and coordinate the operations of a group which may consist of engineer

	Group, or Airborne Engineer Combat Group.							combat or construction battalions, and other assigned or attached units engaged in engineer support activities.
5-54G	Engineer Light Equipment Company, Airborne.	7	0	207	214	1 per airborne corps..	1022.4	To support airborne engineer combat operations with manned engineer construction equipment.
5-58G	Engineer Light Equipment Company.	6	0	206	212	1 per engineer combat group.	1938.5	To support engineer combat operations with manned engineer construction equipment.
5-64G	Engineer Assault Bridge Company, Mobile (Army or Corps).	6	1	198	205	2 per corps	1539.3	To provide personnel and equipment to load, maintain, transport, erect, operate, and maintain stream and gap crossing equipment in support of tactical operations.
5-67G	Engineer Water Supply Company.	5 (5)	0 (0)	119 (71)	124 (76)	1 per field army or 1 per 400,000 troops in a theater army.	495.5	To produce and distribute potable water in the field.
5-77G	Engineer Panel Bridge Company.	3	1	125	129	12 to 15 per field army..	599.5	To provide personnel and equipment to load, transport, maintain and advise on erection of panel bridging equipage. To provide dump trucks for earthmoving and general hauling, when required, by immobilizing bridge loads.
5-78G	Engineer Float Bridge Company.	7	1	221	229	15 per field army	2039.4	To provide technical personnel and equipment to load, maintain, transport, and supervise erection of tactical stream crossing equipment. May haul general cargo in emergencies by immobilizing the bridge loads.
5-97G	Engineer Camouflage Company.	5 (5)	0 (0)	69 (55)	74 (60)	1 per corps	65.3	To plan, supervise, and inspect camouflage installation including deceptive devices. To supervise and inspect camouflage discipline and training.
5-101G	Headquarters and Headquarters Company, Engineer Combat Brigade, Army, Corps or Airborne Corps					1 per army	77.6	To command assigned and attached units and to coordinate the combat engineer activities within the appropriate command. To provide an engineer staff section to either an army or corps headquarters.
	Army Brigade	40	5	101	146	1 per corps		
	Corps or Abn Corps Bde.	28	4	86	118			
5-107G	Engineer Company, Separate Infantry Brigade					1 per separate infantry brigade.	1479.5	To increase the combat effectiveness of the separate infantry brigade by providing engineer combat support. To undertake and carry out a limited infantry combat mission when required.
	With MAB	6	1	250	257			
	With M4T6 or CL60.	6	1	253	260			
5-111G	Headquarters and Headquarters Company, Engineer Construction Brigade.	28	4	100	132	1 per 2 to 4 construction groups.	93.5	To command assigned and attached engineer units and coordinate the engineer construction activities within the appropriate command.

Table 2-1. Engineer Troop Units—Continued

TOE No.	Unit	Authorized strength				Normal assignment	Weight (ST)	Mission
		OFF	WO	EM	Total			
5-112G	Headquarters and Headquarters Company, Engineer Construction Group.	15	7	81	103	1 per 3 to 5 engineer construction battalions.	108.1	To command, control, and supervise assigned and attached units. To perform engineer planning and design functions required in support of field construction. To plan and coordinate the operations of a group consisting of construction and other units engaged in field construction, rehabilitation, or maintenance of facilities in support of Army or Air Force operations.
5-114G	Engineer Construction Support Company.	5 (5)	1 (1)	160 (114)	166 (120)	1 per engineer construction group.	1608.6	To provide rock crushing, bituminous mixing, paving, and other construction support equipment with operators, to increase the capabilities of the construction group in major horizontal and construction projects, such as roads and airfields.
5-115G	Engineer Construction Battalion.	31 (31)	7 (7)	897 (664)	935 (702)	2 to 4 per engineer construction group.	4604.2	To construct and rehabilitate roads, airfield pipeline systems, structures, and utilities for the Army and Air Force in the communications zone and rear areas of the combat zone; and to assist in emergency recovery operations.
5-116G	Headquarters and Headquarters Company, Engineer Construction Battalion.	13 (13)	2 (2)	110 (93)	125 (108)	1 per engineer construction battalion.	190.9	To provide command, construction planning, direction, coordination, and control of the engineer construction battalion and attached units.
5-117G	Engineer Equipment and Maintenance Company, Engineer Construction Battalion.	3 (3)	2 (2)	184 (127)	189 (132)	1 per engineer construction battalion.	1111.2	To support the engineer construction battalion with engineer direct support maintenance and to reinforce the construction capability of the battalion by providing specialists and equipment with operators.
5-118G	Engineer Construction Company, Engineer Construction Battalion.	5 (5)	1 (1)	201 (148)	207 (154)	3 per engineer construction battalion.	1100.7	To excavate, hauls, compact, and grade earth and to provide stabilized earth subgrades for airfields, roads, railroads, levees, supply storage areas, and similar projects. To construct and rehabilitate buildings, port facilities, bridges and drainage structures, pipelines and storage tanks plus related facilities; and to install and repair utilities.
5-124G	Engineer Dump Truck Company.	3 (3)	1 (1)	110 (36)	114 (40)	1 per engineer construction group.	695.1	Operation of dump truck for movement of bulk materials in support of other engineer units.

5-127G	Engineer Company, Separate Armored Bri- gade or Separate Infantry Brigade (Mechanized) With MAB With M4T6 or CL60.	6 6	1 1	253 256	260 263	1 per separate armor- ed brigade or in- fantry brigade (mechanized).	1605.2	To increase the combat effectiveness of the separate armored or infantry (mechanized) brigade by providing engineer combat sup- port. To undertake and carry out a limited infantry combat mission when required.
5-129G	Engineer Company Port Construction.	12 (12)	1 (1)	224 (180)	237 (193)	1 per engineer con- struction brigade or 1 per engineer con- struction group.	1386.7	To perform special engineering work involved in providing port, beach, and POL facilities in support of military operations.
5-137G	Engineer Company, Separate Airborne Brigade.	5	0	151	156	1 per separate air- borne brigade.	218.6	To increase the combat effectiveness of the separate airborne brigade by providing engineer combat support. To undertake and carry out an infantry combat mission when required.
5-145G	Engineer Battalion, Armored Division, or Infantry Division, (Mechanized) With MAB With M4T6 or CL60.	44 44	2 2	971 973	1017 1019	1 per armored divi- sion and 1 per infan- try division (mech- anized).	5241.2	To increase the combat effectiveness of the armored and infantry (mechanized) divi- sions by means of engineer combat support. To undertake and carry out an infantry combat mission when required.
5-146G	Headquarters and Head- quarters Company, Engineer Battalion, Armored Division, or Infantry Division (Mechanized).	19	2	206	227	1 per engineer bat- talion, armored di- vision, or engineer battalion, infantry division (mech- anized).	1064.2	<i>Headquarters:</i> Provides an engineer special staff section for the division and command and staff for the battalion. <i>Headquarters Company.</i> Provides an alternate CP, administration, operations control, com- munications, reconnaissance and engineer intelligence, supply, organization mainte- nance support, supplemental engineer and ordnance construction equipment, and medical service for the battalion. Provides potable water for the division and combat support by the planning and preparation for employment and firing of ADM. Under- takes and carries out infantry combat missions when required.
5-147G	Combat Engineer Com- pany, Engineer Bat- talion, Armored Di- vision, on Infantry Division (Mechanized)	5	0	152	157	4 per engineer bat- talion, armored di- vision, or infantry division, or infantry division (mech- anized).	578.9	To increase the combat effectiveness of the engineer battalion, armored division, and infantry division (mechanized) by providing engineer combat support. To undertake and carry out infantry combat mission when required.
5-148G	Bridge Company, Engineer Battalion, Armored Division, In- fantry Division, or						1100.8	To provide technical personnel and equip- ment to maintain, load, transport, erect, operate, and disassemble tactical assault stream crossing equipment. To accomplish

Table 2-1. Engineer Troop Units—Continued

TOE No.	Unit	Authorized strength				Normal assignment	Weight (ST)	Mission
		OFF	WO	EM	Total			
5-155G	Infantry Division (Mechanized)							in nontactical situations independent bridging or ferry missions as required.
	With MAB	5	0	157	162			
	With M4T6 or CL60.	5	0	159	164			
	Engineer Battalion, Infantry Division					1 per infantry division.	3907.7	To increase the combat effectiveness of the infantry division by means of engineer combat support. To undertake and carry out an infantry combat mission when required.
5-156G	With MAB	44	2	951	997			
	With M4T6 or CL60.	44	2	953	999			
	Headquarters and Headquarters Company, Engineer Battalion, Infantry Division.	19	2	198	219	1 per engineer battalion, infantry division.	931.4	<i>Headquarters.</i> To provide an engineer special staff section for the division and command and staff for the engineer battalion. <i>Headquarters Company.</i> To provide an alternate CP, administration, operations control, communications reconnaissance and engineer intelligence, supply, organization maintenance support, supplemental engineer and ordnance construction equipment, and medical service for the battalion. To provide potable water for the division and combat support by planning and preparation for employment and firing of the ADM. To undertake and carry out the infantry combat missions of a headquarters and headquarters company when required.
5-157G	Combat Engineer Company, Engineer Battalion, Infantry Division.	5	0	149	154	4 per engineer battalion, infantry division.	468.9	To increase the combat effectiveness of the engineer battalion, infantry division by providing engineer combat support. To undertake and carry out infantry combat missions when required.
5-177G	Engineer Pipeline Construction Support Company.	5 (5)	0 (0)	182 (146)	187 (151)	1 per engineer construction group, as required.	517.7	To provide technical personnel and specialized equipment to assist construction and combat engineer units in the construction, rehabilitation, and maintenance (except organizational maintenance) of pipeline systems; to provide a limited independent capability for the construction, rehabilitation, and maintenance of pipeline systems; and to assist using units in specialized repairs.
5-195G	Engineer Combat Battalion, Airborne.	32	4	658	694	As required for support of tactical air force and army airborne operations.	2009.6	To increase the combat effectiveness of joint task force or tactical air force operations by constructing stage I airbase facilities, accomplishing expedient major repairs or modifications of existing facilities, and by

5-196G	Headquarters and Headquarters Company, Engineer Combat Battalion, Airborne.	16	3	135	154	1 per engineer combat battalion, airborne.	184.3	performing general combat engineer construction tasks to support air operations. To provide engineer support to divisional engineer airborne battalions engaged in combat construction activities.
5-197G	Engineer Equipment and Maintenance Company, Engineer Combat Battalion, Airborne.	6	1	239	246	1 per engineer combat battalion, airborne.	1165.8	To provide the command and staff, administration, supply, communication, and medical service for the engineer combat battalion, airborne.
5-198G	Engineer Combat Company, Engineer Combat Battalion, Airborne.	5	0	142	147	2 per engineer combat battalion, airborne.	236.4	To reinforce the construction capabilities of the engineer combat battalion, airborne, by providing air transportable engineer construction equipment with operators, and to enhance the overall capability of the battalion by performing battalion level organizational maintenance for all equipment, and direct support maintenance for engineer and ordnance equipment organic to the battalion.
5-207G	Engineer Company, Separate Light Infantry Brigade.	5	0	163	168	1 per separate light infantry brigade.	462.1	To provide an operating component of the engineer combat battalion, airborne to perform general engineer work facilitating and contributing to the combat construction effort of the battalion in support of STRICOM/AFSTRIKE, or in support of the operations of other forces as directed.
5-215T	Engineer Battalion, Airmobile Division.	36	2	582	620	1 per airmobile division.	1049.5	To increase the combat effectiveness of the separate light infantry brigade by providing engineer combat support. To undertake and carry out an infantry combat mission when required.
5-216T	Headquarters and Headquarters Company, Engineer Battalion, Airmobile Division.	21	2	246	269	1 per engineer battalion, airmobile division.	875.4	To increase the effectiveness of the air-mobile division by performing general and special engineer tasks, and to undertake and carry out infantry missions when required.
5-217T	Combat Engineer Company, Engineer	5	0	112	117	3 per engineer battalion, airmobile di-	58.3	To provide an engineer special staff section for the division and to provide command and staff for the engineer battalion airmobile division. To provide limited administration; communications, reconnaissance, maintenance support, mess, supply and unit level medical service for the engineer battalion. To undertake and carry out combat missions of a headquarters and headquarters company when required.

Table 2-1. Engineer Troop Units—Continued

TOE No.	Unit	Authorized strength				Normal assignment	Weight (ST)	Mission
		OFF	WO	EM	Total			
	Battalion, Airmobile Division.					vision.		plishing general and special engineer tasks. To undertake and carry out infantry combat missions when required.
5-305G	Engineer Topographic Battalion, Army.	16 (15)	6 (6)	346 (286)	368 (307)	1 per field army -----	818.6	To provide engineer surveys, maps, map substitutes, and related technical information and materials as required for an army in the field.
5-306G	Headquarters and Headquarters Company, Engineer Topographic Battalion, Army.	10 (10)	2 (2)	133 (127)	145 (139)	1 per engineer topographic battalion, army.	271.3	To provide command and staff administration, and supply and maintenance support for an engineer topographic battalion, army, and to furnish engineer, surveys, maps, and map substitutes, and related technical information and materials required by an army in the field.
5-307G	Engineer Map Reproduction and Distribution Company, Engineer Topographic Battalion, Army.	3 (2)	1 (1)	106 (64)	110 (67)	1 per engineer topographic battalion, army.	349.6	To reproduce, store and distribute new and existing maps, map substitutes, photomaps, overlays and other engineer intelligence and terrain intelligence material.
5-308G	Engineer Photomapping Company, Engineer Topographic Battalion, Army.	3 (3)	2 (2)	96 (90)	101 (95)	1 per engineer topographic battalion, army.	197.7	To compile and revise planimetric, topographic and special maps and map substitutes and terrain and engineer intelligence material; to perform final evaluation of aerial photography to determine its suitability for mapping purposes; and to extend ground control by photogrammetry for artillery and missile fire control and for surveillance and other purposes, in order to increase the combat effectiveness of the field army.
5-327G	Engineer Topographic Company, Corps.	3	3	136	142	1 per corps -----	447.3	To provide topographic maps, overprinted maps, topographic intelligence, and artillery and topographic survey data in support of corps or independent task force type operations.
5-344G	Engineer Base Map Depot Company.	4 (4)	0 (0)	116 (37)	120 (41)	1 per army group or independent field army.	137.2	To provide for receipt, storage and distribution of maps, geodetic control data, gazetteers, aerial photographs, trig lists, intelligence documents, and related topographic material.
5-346G	Headquarters and Headquarters Detachment, Engineer Base Topo-	7 (7)	2 (2)	60 (53)	69 (62)	1 per TASCOT -----	76.0	To provide combat support to a theater army group by operational planning and technical control of a battalion engaged in topo-

	graphic Battalion.							graphic, artillery, and missile fire control survey, and topographic map compilation and reproduction. To provide geodetic survey control data, trigonometric lists, map reproductions, and other basic engineer intelligence materials to the field army and corps topographic units.
5-347G	Engineer Base Reproduction Company.	2 (2)	2 (2)	96 (69)	100 (73)	1 per engineer base topographic battalion.	34.9	To reproduce maps, map substitutes, charts and allied mapping materials such as map indexes, trig lists, and gazetteers, and engineer terrain and other engineer intelligence material, as required in support of one or more field armies, TASCOT, or the zone of interior.
5-348G	Engineer Base Survey Company.	2 (2)	4 (4)	172 (45)	178 (51)	1 per TASCOT -----	358.4	To accomplish plane or geodetic surveys to provide Class II, 1st order, topographic data, artillery and missile fire control, and to make necessary computations to establish, recover, or adjust existing geodetic control to a given control system for use in new or revised mapping projects and artillery and missile fire control nets. To provide geodetic survey control and other basic data to the field army and corps topographic units.
5-349G	Engineer Base Photomapping Company.	2 (2)	2 (2)	167 (135)	171 (139)	1 per base topographic battalion.	63.9	To provide combat support for a theater army by compiling and revising new and existing multicolor maps and map substitutes, and by extending ground control for artillery and missile fire using photogrammetric means to produce a gridded graphic. To compile and produce reproducible material for engineer intelligence and terrain studies and to evaluate aerial photography to determine its suitability for mapping purposes.
5-401G	Headquarters and Headquarters Company, Engineer Amphibious Brigade.	26	0	84	110	1 per corps as required for amphibious or shore-to-shore operations.	144.0	To command assigned and attached units. To provide the shore party headquarters of a corps landing force during amphibious or shore-to-shore operations. To provide assistance in planning and executing amphibious and shore-to-shore operations including landings on a hostile shore and crossing of major rivers and other water barriers.
5-402G	Headquarters and Headquarters Company, Engineer Amphibious	17	0	73	90	1 per division size landing force.	135.6	To command assigned and attached units. To provide the shore party headquarters of a division landing force during amphibious

Table 2-1. Engineer Troop Units—Continued

TOE No.	Unit	Authorized strength				Normal assignment	Weight (ST)	Mission
		OFF	WO	EM	Total			
	Group.							
5-405G	Engineer Amphibious Battalion.	38	7	671	716	1 per brigade size landing force.	1403.9	or shore-to-shore operations. To provide assistance in planning and executing amphibious and shore-to-shore operations including landings on a hostile shore and crossing of major rivers and other water barriers. To undertake and carry out the infantry combat missions of a headquarters and headquarters company as required. To command and control assigned and attached units. To command, control, and provide the nucleus for the shore party of a brigade-size landing force during amphibious or shore-to-shore operations. To provide tactical amphibian mobility for dismounted combat units in the passage of water barriers. To provide assistance in planning and executing amphibious and shore-to-shore operations including landings on a hostile shore and crossing of major rivers and other water barriers. To undertake and carry out infantry combat missions when required.
5-406G	Headquarters and Headquarters Company, Engineer Amphibious Battalion.	22	4	240	266	1 per engineer amphibious battalion.	402.2	To command assigned and attached units. To command, control, and provide the nucleus of the shore party for a brigade-size landing force during amphibious or shore-to-shore operations. To provide assistance in planning and executing amphibious and shore-to-shore operations including landings on a hostile shore and crossing of major rivers and other water barriers. To undertake and carry out the infantry combat missions of a headquarters and headquarters company as required.
5-407G	Engineer Amphibious Assault Company.	5	1	129	135	2 per engineer amphibious battalion.	103.4	To provide tactical amphibious mobility for dismounted combat units in the passage of water barriers and to provide skills and equipment to train other units assigned amphibious missions in amphibious or shore-to-shore operations. To undertake and carry out infantry combat missions when required.

5-408G	Engineer Amphibious Company.	6	1	173	180	1 per engineer amphibious battalion.	799.9	To provide the control and nucleus for the shore party of a brigade-size landing force during amphibious or shore-to-shore operations. To provide assistance in planning and executing amphibious and shore-to-shore operations including landing on a hostile shore and crossing of major rivers and other water barriers. To undertake and carry out combat missions of an infantry unit when required.
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Table 2-2. Engineer Teams

Designation	Name	Authorized strength				Weight (ST)	Capabilities and basis of allocation
		OFF	WO	EM	Total		
5-500G	ADMINISTRATIVE AND HEAD-QUARTERS TEAMS						
AB	Platoon headquarters, separate	1	--	3	4	3.3	Capability: Provides command and administrative control of two or more teams not a part of a company. Basis of Allocation: One per unit, comprising 40 to 60 individuals which operate separately, and to which no officer is organically assigned.
AC	Company Headquarters	2	--	6	8	11.0	Capability: Provides command administrative control of two or more service platoons or equivalent composition. Basis of Allocation: One per unit comprising two or more platoons composed of teams with an aggregate strength of not less than 120 individuals.
5-510G	FIREFIGHTING TEAMS						
FA	Firefighting headquarters	1	--	3	4	7.1	Capability: Plans for overall area, established organized fire defense, and controls assigned or attached firefighting teams. Basis of Allocation: Normally one per two to four firefighting teams and one water tank team.
FB	Fire Truck	--	--	6	6	10.8	Capability: Provides fire protection and implements fire prevention program for areas housing 5,000 to 10,000 troops, or warehouses and open stockpile storage of 100,000 square feet. Basis of Allocation: One per post, base, camp, or station housing 5,000 to 10,000 troops, or warehouses and open storage area of 100,000 square feet.
FC	Water Truck	--	--	2	2	9.0	Capability: Transports water for firefighting purposes when insufficient water is available. Basis of Allocation: One per firefighting headquarters.
FD	Brush Fire, Truck	--	--	2	2	10.6	Capability: This team, when augmented by volunteer personnel with handtools, furnishes protection against grass or brush fires within the assigned area of operation and can also be utilized to a limited degree to combat structural fires.

Table 2-2. Engineer Teams—Continued

Designation	Name	Authorized strength				Weight (ST)	Capabilities and basis of allocation
		OFF	WO	EM	Total		
5-520G	EQUIPMENT OPERATING TEAMS						
GA	Forestry	1	--	43	44	152.3	Basis of Allocation: One per post, base, camp, or station housing up to 5,000 troops, or warehouses and open storage area of 100,000 square feet. Capability: Provides personnel and equipment necessary to conduct logging and sawmill operations for the production of rough timber and timber piling. Capable of producing 10,000 to 15,000 board feet of rough lumber and timber piling per day. Basis of Allocation: Normally attached to a supply and service battalion of a general support group, to an engineer construction group, or to support independent large scale operations as required.
GB	Acetylene, Nitrogen, and Oxygen Production.	1	--	26	27	130.7	Capability: Provides qualified personnel and equipment to operate one acetylene generating plant of 750 cubic feet per hour capacity, and two oxygen and nitrogen generating plants of 1,000 cubic feet per hour capacity each. Unit operates and maintains machinery to generate acetylene, oxygen, and nitrogen gases, and to store limited quantities of these gases.
GC	Carbon Dioxide and Dry Ice Production.	1	--	12	13	116.9	Basis of Allocation: Normally one per functionalized depot. Capability: Provides qualified personnel and equipment for the generation, storage, and transportation of carbon dioxide in gaseous and liquid form, and in the form of dry ice. Unit operates machinery for the generation of hydrogen and carbon dioxide gases, and to store limited quantities of these gases.
GD	Quarrying and Rock Processing	1	--	73	74	598.9	Basis of Allocation: Normally one per functionalized depot. Capability: Provides qualified personnel and equipment to operate the 225 tons-per-hour crushing, screening, and washing plant and issue product to users. Provides personnel and equipment for drilling and blasting operations required to produce raw stone for the crushing, screening, and washing plant.
GE	Well Drilling	--	--	2	2	19.2	Basis of Allocation: To an engineer construction group as required. Capability: Provides personnel and equipment for drilling and developing water wells; installs casings, screens, and pumps, and develops well to supply water to units or stations at well head. May drill large blast holes for quarrying or to create obstacles. May be issued either percussion or rotary drill; the percussion drill is simple and slow; the rotary drill is more complicated and drills from 20 to more than 100 times as fast.
GF	Well Drilling (Airborne)	--	--	2	2	19.2	Basis of Allocation: Normally attached to an engineer construction or combat unit to provide additional support for drilling operations. Capability: Provides airborne personnel and equipment for drilling and developing water wells; installs casings, screens, and pumps, and develops drilled wells to supply water at the water head. May drill

GG	Water Purification	--	--	4	4	32.4	blast holes up to 4 3/4 inches in diameter and up to 500 feet deep for quarrying or to create obstacles and barriers. Basis of Allocation: Normally attached to engineer combat battalion (airborne) or to the airborne division engineer battalion. May be attached to the engineer light equipment company, airborne.
GH	Water Purification (Central Plant) ...	1	--	11	12	120.8	Capability: Provides personnel and equipment for purifying up to 3,000 gallons of water per hour, and storage facilities for 9,000 gallons. Basis of Allocation: Normally attached to an engineer unit with a water supply requirement.
GI	Water Distillation	--	--	5	5	21.6	Capability: Provides personnel for the operation of a central field water plant. Operates single or multiple standard purification units forming a central field plant supporting 6,000 to 60,000 individuals. Basis of Allocation: Normally attached to an engineer unit with a large water supply requirement.
GJ	Water Transport	--	--	8	8	45.2	Capability: Provides qualified personnel with equipment to provide potable water by distillation, using sea or brackish water as a raw water source. The team has the capability of producing 5,000 gallons of potable distilled water per day by operating on a two shift basis. Basis of Allocation: May be attached to any sized unit or assigned a civic action mission on an as-required basis.
5-530G	CONSTRUCTION, UTILITIES, AND ELECTRICAL POWER TEAMS.						
HA	Diving	1	--	8	9	22.9	Capability: Provides personnel and equipment for short hauls of from 10 to 15 miles to transport water in bulk to dry water points; 5,000 gallons may be transported at one trip. Basis of Allocation: Normally attached to an engineer unit with a water hauling requirement.
HB	Pipeline Design	2	--	4	6	6.0	Capability: Provides personnel with equipment to accomplish shallow or deep water diving in support of port construction and rehabilitation and construction of underwater pipelines. Basis of Allocation: Normally one per engineer group when engaged in major port or underwater pipeline projects.
HC	Real Estate	5	--	11	16	12.8	Capability: Provides qualified personnel to assist in the design and supervision of specialized pipeline construction projects. Assists in site reconnaissance and selection of major tank farm locations, pipeline routes, and pertinent structures, including off-vessel discharging and loading facilities and fixed dispensing equipment; assists in design and layout, preparation of construction specifications, selection of material and equipment, and formulation of a construction plan, and assists in the management and supervision of construction operations. Basis of Allocation: Normally to an engineer construction brigade on an as-required basis.
							Capability: Provides qualified personnel for surveying, inventorying, and recording the location, extent, and the condition of real property required or occupied by army forces. Inventories and records installed and personal property located in air installations, bakeries, factories, foundries, hospitals, hotels, machine shops, mills, private dwellings,

Table 2-2. Engineer Teams—Continued

Designation	Name	Authorized strength				Weight (ST)	Capabilities and basis of allocation
		OFF	WO	EM	Total		
HD	Welding	--	--	2	2	11.3	public utility plants, schools, and railroad maintenance and operating facilities when augmented by appropriate technical specialists. Basis of Allocation: Normally to a field army support command, logistical command, or area command as required. Capability: Provides qualified welders and equipment for support of units where welding requirements exist which are beyond organic capabilities.
HE	Utilities, Electric Power	1	--	30	31	91.7	Basis of Allocation: Normally to an engineer construction brigade, construction group, or functionalized GS group. Capability: Provides for maintenance of utilities at installations with a population of up to 2,500; provides post engineer type service to oversea or theater of operations installations; maintains utilities service and repair, including refrigeration maintenance.
HF	Utilities	1	1	50	52	106.5	Basis of Allocation: Normally on the basis of one team for each camp, post, depot, or installation with a population of up to 2,500. Capability: Provides personnel and equipment for maintenance of utilities at installations of from 2,500 to 4,000; provides post engineer type service in oversea or theater of operations installations; maintains utilities and furnishes utilities service and repair, including refrigeration maintenance.
HG	Utilities	3	1	85	89	----	Basis of Allocation: Normally one per oversea camp, base, depot, or installation having a population of from 2,500 to 4,000. Capability: Provides personnel and equipment for maintenance of utilities at installations of up to 10,000 individuals; provides post engineer type service in oversea or theater of operations installations; maintains utilities and furnishes utilities service and repair, including refrigeration maintenance.
HH	Powerplant Operating and Maintenance.	1	--	15	16	4.1	Basis of Allocation: Normally one per oversea camp, base, depot, or installation having a population of up to 10,000. Capability: Provides qualified personnel with equipment for the operation and maintenance of electrical powerplants containing from one to three diesel engine generators of 300 to 2,500 KW capacity.
HI	Floating Powerplant (Nuclear)	2	1	65	68	7.8	Basis of Allocation: Normally to an engineer construction brigade. Capability: Provides qualified personnel with equipment to supply large amounts of electric power (10-50 megawatts) from nuclear fuel in support of military operations in coastal areas or along navigable inland waterways. The plant requires towing to the desired operating location. It is operated while berthed at a suitable wharf or pier, or anchored offshore. When it is operated at an offshore anchorage position, power is distributed to shore through submarine power cables. Approximately two megawatts of electric power from auxiliary diesel generators is available on the plant for ship's service, start-up, and limited support to shore facilities during preparations for reactor

HJ	Utilities, Electric Power	1	--	13	14	29.7	plant operations. The reactor plant can supply power for long periods of time with little logistical support. Basis of Allocation: Normally to a field army support command, logistical command, or area command on an as-required basis. Capability: Provides qualified personnel with equipment to install high voltage electric powerlines, and to maintain approximately 60 miles of high voltage electric powerlines. Basis of Allocation: Normally one per two electric power generating plants of 300 to 2,500 KW capacity.
5-540G	TOPOGRAPHIC AND INTELLIGENCE TEAMS						
IA	Topo Planning and Control	8	--	12	20	15.6	Capability: Map program and other engineer intelligence planning, and technical supervision of map and engineer intelligence compilation; surveying and geodetic activities, including supervision, collection, maintenance, and dissemination of engineer topographic and artillery fire control survey data; coordination of map and engineer intelligence reproduction to include evaluation of reproduction facilities, and planning the employment of such facilities; supervision of the topographic map and engineer intelligence program, including the operation of map and engineer intelligence depots and supply points throughout the command. Maintains liaison with higher headquarters and allied armies. Supervises the indigenous reproduction and mapping agency programs used to accomplish the mission. Basis of Allocation: One per theater army headquarters, army group headquarters, field army headquarters, or topographic battalion as required.
IB	Geodetic Survey	3	1	16	20	23.3	Capability: Provides qualified personnel with equipment to accomplish, instruct in, or supervise first order astronomic observation surveys and computations in a theater of operations survey operation, or in the field army for guided missile and artillery fire control support. Basis of Allocation: Normally one per topographic battalion.
IC	Survey	--	1	14	15	19.1	Capability: Provides qualified personnel and equipment to perform second, third, and fourth order topographic and artillery fire control support surveys. Tower and FADAC computer support is provided by the supported unit. Basis of Allocation: Normally assigned to a topographic unit.
ID	Survey (Airborne)	--	1	14	15	19.1	Capability: Provides jump-qualified personnel with equipment to perform second, third, and fourth order topographic and artillery fire control support surveys for an airborne corps or independent airborne force to include support of TOE 5-195, Engineer Combat Battalion (Airborne). Tower and FADAC computer support must be provided by others. Basis of Allocation: Normally assigned to a topographic unit.
IE	Photographic Evaluation	--	1	8	9	27.9	Capability: Provides qualified personnel with equipment to evaluate USAF photographic units' production of photography to determine its suitability for the compilation of military topographic maps. Basis of Allocation: Normally to an engineer topographic battalion.

Table 2-2. Engineer Teams—Continued

Designation	Name	Authorized strength				Weight (ST)	Capabilities and basis of allocation
		OFF	WO	EM	Total		
IF	Photomapping Platoon	1	1	42	44	98.3	Capability: Provides qualified personnel with equipment for the preparation and revision of topographic planimetric and special maps, photomaps, mosaics, and other engineer intelligence data, to include final drafting of map manuscripts, color separation drawings and scribed manuscripts, grids, and marginal data. Requires water supply support from supported unit. Basis of Allocation: May be attached to an engineer topographic battalion, when mapping operations require additional effort.
IG	Map Reproduction Platoon	1	1	49	51	168.6	Capability: Provides qualified personnel and equipment for the production of maps and other engineer intelligence material from original manuscripts. Basis of Allocation: Normally attached to an engineer topographic unit when mapping operations require additional effort.
IH	Map Distribution Platoon	1	--	37	38	61.6	Capability: Provides qualified personnel and equipment for the receipt, storage, and distribution of maps and other engineer intelligence material for a base, army, or corps. This platoon may operate a depot. Basis of Allocation: Normally one to three per topographic battalion to operate forward depots.
II	Military Hydrology	5	--	17	22	30.1	Capability: Capable of predicting river stages and discharges, and natural and artificial flood velocities, depths, and widths, in a drainage basin with an area up to 1,000 square miles; preparing hydrologic analyses of river crossings sites; preparing studies of hydrologic and hydraulic factors involved in military installations from a point of view of flood incidence; providing technical advice on hydraulic features of logistic operations and on equipment for use in water. When necessary the theater commander will provide for the allocation of additional communication facilities and for joint operation of Air Weather Service Units and Corps of Engineers units. Basis of Allocation: Normally one per field army or independent corps; may be assigned to a geographic area, determined by stream and drainage basin characteristics.
IJ	Terrain	6	--	7	13	19.5	Capability: Provides qualified personnel with equipment for the collection, evaluation, and dissemination of terrain data, the production of military terrain studies, and for consultant services in military geology and hydrology. Basis of Allocation: Normally one per field army.
5-550G	DREDGE TEAMS						
JA	Dredge Cutterhead, Pipeline 12"-16" ..	5	6	31	42	375.6	Capability: Provides for the operation and maintenance of one diesel powered 12"-16" pipeline, cutterhead type engineer dredge. Basis of Allocation: Normally to an engineer brigade or logistical command.
JB	Dredge Cutterhead, Pipeline 18"-24" ..	5	7	55	67	624.7	Capability: Provides for the operation and maintenance of one diesel-

							electric or steam powered 18"-24" pipeline cutterhead type engineer dredge.
							Basis of Allocation: Normally to an engineer brigade or logistical command.
JC	Dredge Seagoing Hopper, 500-900 Cu Yd (DSL).	4	9	51	64	3.7	Capability: Provides for operation and maintenance of one engineer dredge, seagoing hopper, diesel-electric powered, 500-900 cubic yard.
							Basis of Allocation: Normally to an engineer brigade or logistical command.
JD	Dredge Seagoing Hopper, 3,000 Cu Yd (DSL or Steam).	7	12	70	89	3.9	Capability: Provides for operation and maintenance of one engineer dredge, seagoing hopper, diesel-electric or steam powered, 1600-3500 cubic yard.
							Basis of Allocation: Normally to an engineer brigade or logistical command.
JE	Dredge Seagoing Hopper, 6000-8100 Cu Yd (Steam).	10	9	79	98	3.9	Capability: Provides for operation and maintenance of one engineer dredge, seagoing hopper, steam powered, 6000-8100 cubic yard.
							Basis of Allocation: Normally to an engineer brigade or logistical command.
5-560G	ENGINEER CIVIC ACTION TEAMS						
KA	Engineer Civic Action Headquarters	2	1	7	10	6.1	Capability: Provides the headquarters engineer staff and headquarters for a special action forces command and control element. Provides staff planning and coordination of subordinate teams. Provides administrative support for subordinate teams.
							Basis of Allocation: One per two to three engineer control teams.
KB	Engineer Civic Action Control	2	--	3	5	4.9	Capability: Provides engineer staff personnel for a special action forces command and control element. Provides staff planning, coordination, and administrative support for subordinate engineer teams.
							Basis of Allocation: One per four to nine engineer advisory teams.
KC	Engineer Civic Action Advisory	1	--	4	5	4.1	Capability: Advises host country engineer forces on civic action type projects such as farm-to-market roads, bridges, village wells, sanitation developments, and construction of schools, hospitals, or other type public buildings. Assists host country engineer units in preparing to support their own technical troops for internal defense/development operations. Assists and advises U. S. military forces when committed in support of host country forces. Supervises operations with host country counterparts.
							Basis of Allocation: One per host country force comparable in size to a U. S. Army engineer combat battalion or one per municipal area for civic action as required.
5-570G	ENGINEER COMBAT SUPPORT TEAMS.						
MA	Atomic Demolition Munitions Platoon Headquarters, Separate.	1	--	4	5	11.7	Capability: Command and administrative control of two to six atomic demolition munitions teams. Provides supported unit with technical liaison, advisory, and limited planning services for the employment of atomic demolition munitions. Commands subordinate teams in employing and executing the firing of ADM. Coordinates the supply and resupply of ADM prescribed load.
							Basis of Allocation: One per two to six ADM Squads (Team MC) to

Table 2-2. Engineer Teams—Continued

Designation	Name	Authorized strength				Weight (ST)	Capabilities and basis of allocation
		OFF	WO	EM	Total		
MB	Atomic Demolition Munitions Liaison	1	--	1	2	2.0	provide an ADM employment capability to the engineer combat battalion, army, other U.S. Army combat units, task forces, or allied engineer units. Capability: Provides an atomic demolition munitions liaison officer to the headquarters of supported U.S. and Allied units not otherwise authorized an ADM qualified officer. Provides technical knowledge, advisory, and limited planning services to the unit to which assigned. Performs liaison between the headquarters to which assigned and supporting ADM teams for the employment of ADM. Basis of Allocation: One per headquarters assigned ADM missions and not authorized an ADM qualified officer.
MC	Atomic Demolition Munitions Squad	--	--	5	5	9.5	Capability: Assembles, prepares for firing, detonates on order, or if necessary, recovers, disassembles, or destroys atomic demolition munitions. Must be supported by the unit to which attached for ADM storage, transport, security, site preparation, and team administration. Basis of Allocation: One or more to provide a required ADM employment capability to the engineer combat battalion, army, or other U.S. Army combat units, task forces, or Allied forces, and as required to increase the ADM capability of the divisional engineer battalion.
5-590T GK	ENGINEER TENTATIVE TEAMS. Engineer Concrete Mixing and Paving	1	--	21	22	96.1	Capability: Capable of producing 100 to 125 cubic yards of concrete per hour of operation at a central mix plant; placing, finishing, and curing up to 560 square yards of rigid pavement, 8 inches thick, from 20 to 25 feet wide, per hour of operation; performing organizational maintenance on organic equipment, and on-site direct support maintenance on the paver-finisher, batching-mixing plant, curing machine, subgrade planer, and 100 KW generator; and working on a two-shift basis. The supported unit must provide dump trucks and drivers to supply the batching-mixing plant and to haul concrete to the paver-finisher. It must also provide additional labor for plant set-up and operations. Basis of Allocation: Normally attached to an engineer construction group as required.

CHAPTER 3

LOGISTICAL DATA

Section I. Equipment Other Than Motorized

3-1. Sets Common to Engineer TOE

Table 3-1 gives the nomenclature, cubages, and weights of sets common to engineer units.

Table 3-1. Sets Common to Engineer TOE Units

Fed Stock No.	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu ft	Weight (lb)	TOE 5-
3895-641-7973	Asphalt Mixing and Paving Set -----	323.0	104.0	114.0	----	350,100 359	114
6655-664-4654	Astronomic Position Set -----	31.6	26.6	20.0	----	359	38
3820-931-4509	Auger, Earth, Skid Mounted -----	128.0	43.0	58.0	----	6,155	54, 58, 117
1945-672-3582	Barge Assembly Set: 5 x 12 -----	----	----	----	----	----	129
1945-672-3581	Barge Assembly Set: 3 x 7 -----	----	----	----	----	----	129
1945-672-3580	Barge Assembly Set: 6 x 18 -----	----	----	----	----	----	129
7610-264-4645	Book Set: Topographic General Purpose -----	51.3	38.8	15.8	----	433	306, 346, 348, 540
7610-264-4647	Book Set: Topographic Battalion Photomapping Com- pany.	20.9	14.9	11.3	1.982	67	308, 349, 540
7610-264-4648	Book Set: Topographic Reproduction Company -----	21.3	17.0	13.5	----	74	307, 347, 540
7610-264-4652	Book Set: Water Supply -----	----	----	----	----	----	67, 301
7610-264-4653	Book Set: Forestry Operations -----	11.2	8.5	3.8	.211	6	112, 301, 520
7610-664-0435	Book Set: Combat Group -----	12.5	10.0	12.5	----	27	26, 36, 38, 52, 54, 58, 97, 112, 114, 116, 117, 118, 129, 146, 156, 197, 401, 402, 406, 500
7610-664-0436	Book Set: Machinist Weld and Electric Repair -----	9.8	6.8	13.0	----	15	54, 64, 114, 117, 177, 237, 278, 530
7610-664-0437	Book Set: Construction Group -----	20.0	13.7	15.8	----	132	52, 111, 112, 116, 129, 196, 530, 560
7610-664-0438	Book Set: Field Army Engineer Section -----	12.5	7.8	10.08	.515	16	101, 111, 112
7610-282-8249	Book Set: GHQ-Trans RY SER TRANS COM RY TRANS GP REF Library.	27.0	24.0	12.0	4,500	69	520, 530
5420-530-3784	Bridge Fixed: Pony Truss Portable Panel Bailey Type --	166.0	306.6	306.6	----	207,638	77
5420-171-4519	Bridge Floating: Highway Aluminum Deck Balk Sup- erstructure.	267.3	217.9	217.9	----	163,320	78, 107, 127, 148
5420-059-9082	Bridge Floating: Highway Class 60, 135 Foot -----	----	----	----	----	----	78, 107, 127, 148
5420-267-0009	Bridge Floating, Foot -----	332.5	153.0	86.0	----	19,318	78
5420-542-4719	Bridge Floating, Raft Section Light Tactical -----	----	----	----	----	----	78, 107, 127, 148
6780-408-5521	Camera Expendable Supply Set Still Picture -----	4.5	16.0	6.0	32.900	454	52, 112, 401
3610-598-5811	Camera Topographic Reproduction Set Truck Mounted --	327.0	97.0	130.5	2,395.4	24,550	307, 327
6720-301-4685	Camera Set Still Picture: Designed for General Photo- graphs.	11.8	8.0	6.5	----	8	36, 52, 101, 111, 146, 156
6720-985-6795	Camera Set Still Picture for Studio and General Photo --	22.8	14.8	8.0	----	33	26, 36, 52, 101, 111, 112, 116, 146, 156, 196, 401, 406, 500, 530
1080-375-8983	Camouflage Net Set Field Artillery and Drape 72 Ft with 88 ft Long.	45.8	25.4	15.0	44.612	412	500
1080-375-8980	Camouflage Training Set Company -----	----	----	----	----	----	97

6675-526-4719	Cartographic Section Topographic Mapping Set, Truck Mounted.	328.8	99.3	131.3	2,501.2	22,610	308, 327
6675-641-3609	Computing and Drafting Equipment Set and Field Survey Data.	859.2	480.0	480.0	----	1,470	306, 348, 540
6675-526-4824	Copy and Supply Section Set Topographic Mapping Set, Truck Mounted.	326.8	98.3	131.8	2,450.2	24,370	308
3820-030-1612 -641-4968	Crusher Jaw, Gasoline Driven, Wheel Mounted 15 TPH	352.3	84.9	129.7	2,062.3	16,000	54, 147
3820-247-9913	Crushing and Screening Plant, Gasoline Driven Semi-trailer Mounted 35 TPH.	360.0	108.0	122.5	3,298.3	31,482	54, 58
3820-360-2475	Crushing, Screening, and Washing Plant, Diesel Driven Wheel Mounted 50 TPH Dual Unit 33R.	480.0	124.0	144.0	----	64,000	520
3820-752-6462	Crushing and Screening Plant, Diesel and Electric Driven, Wheel Mounted 75 TPH.	----	----	----	----	161,910	114, 117
	Crusher Jaw 5157 -----	489.0	106.0	143.0	----	72,200	----
	Crusher Roll 52308 -----	495.0	118.0	143.0	----	61,450	----
	Conveyor -----	432.0	120.0	112.0	----	9,420	----
	Conveyor -----	432.0	120.0	112.0	----	9,420	----
	Conveyor -----	432.0	120.0	112.0	----	9,420	----
3820-527-8577	Crushing, Screening, and Washing Plant; Diesel and Electric Driven Wheel Mounted 225 TPH.	----	----	----	----	331,850	520
	Dehydrator Sand -----	320.0	110.0	117.0	----	15,840	----
	Crusher Roll MD 300 -----	560.0	122.0	169.0	----	64,480	----
	Crusher Jaw MD 153 -----	441.0	119.0	160.0	----	72,120	----
	Pump Wheel Mounted -----	135.0	86.0	122.0	----	6,500	----
	Crusher Roll MD 42V -----	370.0	122.0	161.0	----	55,700	----
	Crusher Roll MD 54V -----	520.0	116.0	158.0	----	75,640	----
	Scrubber and Washer -----	306.0	117.0	162.0	----	35,070	----
4620-269-0181	Distillation Equipment Set Thermocomp, Trailer Mounted 150 GPH.	153.0	85.6	78.0	590.5	5,000	520
4220-912-9092	Diving Equipment Set, 1 Person Scuba Open Circuit ----	----	----	----	----	----	64, 129, 406, 530
4220-269-7906	Diving Equipment Set, 2 Persons 100-Foot Depth -----	81.0	48.0	36.0	81.000	1,150	129, 530
4220-269-7905	Diving Equipment Set 2 Persons 120-Foot Depth -----	85.0	82.0	64.0	----	4,115	129, 530
6675-641-3618	Drafting and Duplicating Equipment Set; Small Sketching Notes and Orders.	33.0	24.0	12.8	----	147	26, 54, 58, 64, 118, 148, 197, 267, 500, 560
6675-641-3610	Drafting Equipment Set Battalion: Charts Sketches and Overlays.	47.2	34.1	12.3	----	18	26, 36, 38, 52, 97, 101, 111, 112, 114, 116, 129, 146, 156, 196, 207, 279, 301, 306, 401, 402, 406, 500, 530
6675-526-7323	Drafting Equipment Set Supplementary: Plastic Scribing.	9.3	8.3	5.0	.211	6	308, 327, 349

Table 3-1. Sets Common to Engineer TOE Units—Continued

Fed Stock No.	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu ft	Weight (lb)	TOE 5-
6675-641-3615	Drafting Equipment Set Topographic Battalion, Headquarters and Service Company, and Operations, Plans, Mapping, Drawing and Charting.	138.0	80.0	81.0	----	5,600	112, 301, 346
6675-641-3616	Drafting Equipment Set Topographic Battalion, Photomapping Company and Map Revision, Compilation, and Color Separation.	175.0	107.5	123.3	----	29,800	349
6675-641-3529	Drafting Instrument Set: Field -----	11.04	5.3	1.08	.043	1	116, 401
5180-540-3833	Erection Outfit Low Bolted Storage Tanks and Single Ring Tanks.	----	----	----	----	----	129, 177
5180-566-5549	Erection Outfit High Bolted Storage Tanks: Steel Storage Tanks.	----	----	----	----	----	129, 177
4210-269-7899	Firefighting Equipment Set: Auxiliary Equipment For Fire Truck.	----	----	----	53,000	5,398	510
4210-393-0349	Firefighting Equipment Set: Truck Mounted Brush ----	336.0	96.0	144.9	1,662.6	18,440	510
4210-393-0353	Firefighting Equipment Set: Truck Mounted -----	282.9	93.9	108.0	1,662.6	18,820	510
6230-299-5642	Floodlight Set Electric, Portable 6 Floodlights Mast Mounted 5 kw, 120-208 Volts.	76.3	9.6	9.6	----	780	54, 58, 114, 117, 118, 129, 177, 197, 267, 408, 520
4210-293-7664	Forced Entry and Rescue Equipment Set, Aircraft Crash.	43.0	20.5	34.5	----	391	52, 112
3655-390-8550	Generating and Charging Plant: Acetylene, Semi-trailer Mounted 750 Cu Ft per hr.	370.0	98.5	130.5	2,752.4	32,855	520
3655-390-8562	Generating and Charging Plant: Carbon Dioxide, Semi-trailer Mounted 300 lb per hr.	429.0	110.0	138.0	3,768.6	48,000	520
3655-293-4106	Generating and Charging Plant: Oxygen-Nitrogen, Semitrailer Mounted, Electric Driven.	261.0	100.0	139.0	----	57,304	520
4910-754-0652	Hoisting Unit Truck Mounting: Organizational Maintenance Set No. 7.	144.0	66.3	16.5	----	855	67, 530
3895-641-7982	Jetting Set Portable, Pile Driver -----	93.5	37.5	59.2	75,625	1,485	129
3610-293-8659	Laboratory Section: Topographic Reproduction Set, Truck Mounted.	324.0	97.0	130.5	----	18,580	307, 327
6230-299-6474	Light Set: Chart Field and Portable Command Post ----	19.0	18.5	18.5	----	145	124, 196
6230-299-7080	Light Set General Illumination, 15 kw -----	107.0	76.0	73.0	----	4,050	112, 279, 347, 349
6230-299-7077	Light Set General Illumination, 25 Outlet -----	32.0	25.7	25.7	----	299	07, 26, 27, 36, 38, 52, 54, 58, 64, 67, 77, 78, 97, 101, 107, 111, 112, 114, 116, 117, 118, 124, 127, 129, 137, 146, 147, 148, 156, 177, 196, 197, 207, 237, 267, 278, 301,

							306, 307, 308, 327, 344, 346, 348, 401, 402, 406, 407, 408, 520
3695-287-6913	Logging Arch Tractor MED: YM-9	158.4	121.8	150.5	1,733.4	11,136	520
6675-641-3625	Map Distribution Set, Portable	133.3	40.0	50.0	----	4,000	327, 344, 540
3610-294-7830	Map Layout Sections: Topographic Reproduction Set, Truck Mounted.	324.0	97.0	130.5	----	18,090	307, 327
6675-526-4788	Map Revision Section Topographic Mapping Set, Truck Mounted.	329.3	98.8	131.8	2,481.5	22,190	308, 327
9905-375-9180	Minefield Marking Set; Engineers with Components	34.3	36.4	36.4	----	854	36, 301
6675-526-4836	Multiplex Section Topographic Mapping Set, Truck Mounted.	330.0	98.0	130.0	2,464.7	20,280	308, 327
6780-607-0030	Photographic Set Printing and Processing, ES-20	----	----	----	----	----	52, 101, 111, 112, 402, 540
6780-498-9921	Photographic Set Picture Taking and Processing ES-12.	23.0	17.0	24.0	7.300	127	36, 97, 156
6675-526-4631	Photomapping Section Topographic Mapping Set, Truck Mounted.	329.0	98.0	132.0	2,483.9	22,890	308, 327
3610-691-1707	Photomechanical Process Section Topographic Repro- duction Set, Truck Mounted.	323.0	96.8	130.5	----	20,060	307, 327
3610-294-7829	Plate Process Section: Topographic Reproduction Set, Truck Mounted.	323.0	96.8	130.5	----	20,750	307, 327
6675-641-3619	Plotting Instrument Set Stereoplotter Multiplex Control Booth.	151.0	86.0	77.0	----	4,600	349, 540
6675-641-3620	Plotting Instrument Set Stereoplotter Multiplex Drafting Unit.	----	----	----	----	----	540
6675-641-3621	Plotting Instrument Set Stereoplotter Multiplex Laboratory.	161.0	87.0	74.0	----	24,098	349, 540
6675-641-3622	Plotting Instrument Set Stereoplotter Multiplex Plotting Booth.	139.0	65.0	50.0	----	7,380	349, 540
3540-293-9180	Preservation and Packaging Equipment Set #1, Semi- trailer Mounted.	292.3	98.3	128.0	----	13,000	279
3610-204-3137	Press Section, Topographic Reproduction Set, Truck Mounted.	323.0	97.0	130.0	----	24,180	307, 327
6675-526-4629	Rectifier Section Topographic Mapping Set, Truck Mounted.	329.0	99.0	131.5	2,499.7	24,295	308, 327
3610-753-2263	Reproduction Set Dazotype Machine Moist Process: 10 Components.	19.5	15.3	8.8	44.562	610	36, 52, 101, 111, 112, 116, 129, 146, 156, 196, 346, 349, 401, 402, 406, 500, 540
4940-754-0737	Shop Set Contact: Emergency Repair	----	----	----	82.200	2,236	406
4910-754-0714	Shop Set Fuel: Electrical System	72.6	36.2	42.0	167,000	2,253	406
6675-641-3632	Sketching Set Surveying: Military Field Sketching	17.0	16.3	4.9	.920	22	27, 37, 101, 107, 111, 127, 137, 147, 157,

Table 3-1. Sets Common to Engineer TOE Units—Continued

Fed Stock No.	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu ft	Weight (lb)	TOE 5-
							196, 198, 207, 301, 406, 540, 560
6675-641-3633	Stereometer Set Stereocomparagraph Photogram- metrics.	77.0	58.0	37.5	----	862	540
6675-543-1292	Supplementary Equipment Set Topographic Photo- mapping.	48.0	36.0	24.0	----	2,600	308, 327
6675-641-3602	Surveying Set Precise Traversing and Taping: Stadia Methods.	48.0	36.0	12.0	----	375	38, 306, 327, 348, 540
6675-641-3601	Survey Set Topo Co Survey Draft Comput: Office Equip.	84.0	48.0	36.0	----	5,150	306, 327
6675-641-3600	Surveying Set Triangulations: Principal OBS and Sig Tender.	77.0	28.0	24.0	----	405	38, 306, 327, 348, 540
6675-641-3603	Surveying Set Triangulation Reconnaissance and Specialized.	47.5	29.0	12.0	----	202	306, 348, 540
6675-641-3604	Survey Set Precise Levels Spirit Level Second Order Accuracy.	12.0	12.0	18.0	----	29	306, 327, 348
6675-641-3605	Surveying Set Precise Baseline and Spec Set First Order Accuracy.	36.0	24.0	24.0	----	260	348, 540
6675-641-3634	Surveying Set Supplementary Equipment Topographic Battalion.	85.0	28.0	26.0	----	690	38, 348, 540
6675-641-3639	Surveying Set General Purposes Planimet Const and Topo Survey.	48.3	39.5	24.3	----	474	26, 36, 52, 107, 111, 112, 116, 129, 146, 156, 196, 207, 301, 540
6675-641-3640	Surveying Set Plane Table: 5 man Topo Survey -----	83.8	33.5	25.3	40.486	489	38, 348, 540
6675-045-8897	Surveying Set Astronomic Position -----	59.1	35.8	24.1	----	1,600	306, 348, 540
4931-045-6540	Test Set Computer Logistics Unit -----	36.9	34.6	23.5	17.386	250	306, 327, 348
6630-641-3641	Test Set Concrete -----	49.0	45.7	45.7	----	2,307	111, 112, 116, 301, 500
6625-973-2117	Test Set Electronic Circuit Plug-in Unit and AN/GRM-55.	9.0	7.8	5.6	.473	8	07, 26, 27, 36, 37, 52, 64, 78, 101, 107, 111, 112, 116, 118, 127, 137, 146, 147, 148, 156, 157, 177, 196, 207, 237, 278, 306, 327, 348, 401, 402, 406, 407, 408
6625-820-0064 6625-376-4939	Test Set Electron Tube and TV-7/U -----	15.6	8.8	6.5	----	19	07, 26, 27, 36, 37, 52, 64, 78, 101, 107, 111, 112, 116, 118, 127, 137, 146, 147, 148, 156, 157, 177, 196, 207, 237, 278, 306,

6625-892-5542	Test Set Radio and AN/VRM-1	10.0	7.8	6.1	----	6	327, 348, 401, 402, 406, 407, 408
6630-641-3643	Test Set Soils	36.3	17.4	12.0	----	45	07, 26, 27, 36, 37, 52, 64, 78, 101, 107, 111, 112, 116, 118, 127, 137, 146, 147, 148, 156, 157, 177, 196, 207, 237, 278, 306, 327, 348, 401, 402, 406, 407, 408
6635-542-1284	Test Set Soil Trafficability	28.1	13.0	3.1	----	17	52, 111, 112, 116, 196, 301, 560
6625-973-3411	Test Set Transponder Set: AN/APM-156	11.5	9.5	9.5	----	30	26, 36, 52, 101, 107, 127, 146, 156, 401, 402, 406, 408
4933-987-9816	Tool Set Aircraft Armament Repairman	----	----	----	2.280	34	52
5180-900-8559	Tool Set Air Assault Engineer Squad	----	----	----	----	----	27, 137
4920-944-0990	Tool Set Organizational Maintenance Army Aircraft Set A.	----	----	----	----	----	101, 111, 112
4920-944-0985	Tool Set Organizational Maintenance Army Aircraft Set A Supplemental.	----	----	----	----	----	101, 111, 112
4920-944-1003	Tool Set Organizational Maintenance Army Aircraft Set B.	----	----	----	----	----	52, 112
4940-754-0743	Tool Set Vehicle Full Tracked, Organizational Main- tenance Supplemental No. 2.	108.0	39.0	59.0	----	3,076	117, 156, 306, 406, 407
3433-264-6206	Torch Outfit Cutting and Welding Set No. 2	54.0	36.0	24.0	----	858	37, 67, 117, 118, 129, 147, 157, 177, 196, 327
3433-264-6205	Torch Outfit Cutting and Welding Set No. 3	54.0	36.0	24.0	----	858	07, 38, 78, 129, 500, 520, 530
3433-294-6743	Torch Set Cutting and Welding Medium Duty	12.8	7.08	3.6	----	----	64, 77, 148
5445-273-6738	Tower Erection Set Topographic	----	----	----	----	----	306, 348, 540
4610-902-3106	Water Purification Set, Portable 600 GPH	----	----	----	----	----	137
4610-202-6925	Water Purification Equipment Set Truck Mounted Dia- tomite Filter 1500 GPH.	----	----	----	----	----	36, 107, 116, 127, 146, 156, 207
	Truck Van	280.5	99.8	126.5	----	18,940	----
	Trailer M105A2	166.0	83.0	55.0	----	2,670	----
4610-202-8701	Water Purification Equipment Set Trk Mtd Diatomite Filter 3000 GPH.	----	----	----	----	----	67, 520
	Truck Van	339.5	99.0	127.0	----	21,420	----
	Trailer M105A2	166.0	83.0	55.0	----	2,670	----
6630-262-7288	Water Quality Control Set	17.5	12.0	21.8	----	85	26, 36, 38, 67, 107, 116, 127, 137, 146,

Table 3-1. Sets Common to Engineer TOE Units—Continued

Fed Stock No.	Nomenclature	Length (in.)	Width (in.)	Height (in.)	Cu ft	Weight (lb)	TOE 5-
3431-731-4163	Welding Set ARC: Inert Gas Shield Water Cool General Purpose Aluminum Weld.	48.0	36.0	24.0	----	590	156, 196, 207, 520, 530 26, 146, 530
3431-972-7672	Welding Set ARC: Inert Gas Shielded DC 115V -----	30.5	21.0	16.3	----	142	26, 36, 54, 64, 77, 78, 107, 117, 118, 124, 127, 129, 156, 177, 197, 406, 408, 520, 530
3431-287-5404	Welding Shop Cargo Trailer Mounted 300 AMP -----	166.0	83.0	83.0	----	5,845	36, 54, 77, 78, 114, 117, 118, 124, 129, 146, 156, 177, 196, 197, 237, 278, 406, 407, 530

3-2. Radio Facilities Available to Engineer Units

a. The radio available to or associated with engineer troop units, with their frequencies, emissions, normal ranges, and normal usage, are listed in table 3-2. Common abbreviations used in radio nomenclature are as follows:

a.c.	alternating current
AF	audio frequency
AM	amplitude modulation
BA	battery
c.p.s.	cycles per second
c.w.	continuous wave
d.c.	direct current
FM	frequency modulation

f.s.	frequency shift
f.s.k.	frequency shift keying
GN	generator
HF	high frequency
HV	high voltage
Hz	Hertz per second (same as c.p.s.)
LF	low frequency
LV	low voltage
m.c.w.	modulated continuous wave
MHz	megahertz
rcvr	receiver
RT	receiver-transmitter
SW	sky wave
v	volt
VF	voice frequency
w	watt
xmtr	transmitter

Table 3-2. Characteristics of Radios Organic to Engineer Units

Radio set	Operating range (km)	Frequency range (MHz)	Modulation	Emission	Remarks
AN/GRC-19	80-Voice 120-CW.	1.5-20.0 rcvr .5-32.0.	AM	Voice CW.	Forward area vehicular set. Replaces SCR-193 and SCR-506. Provides communication between vehicles from vehicle to air or ground set. Voice and radio teletype service at the same time is possible when connected to radio-teletype equipment which is not supplied as a part of the GRC-19.
AN/GRC-26	1,600	2-18.0	AM	Voice CW RATT.	Mobile medium powered, long range, point to point, and ground to air. Equipment includes teletypewriter radio receiver and transmitter, perforator transmitter, frequency shift exciter, dual diversity converter and associated items installed in a field type shelter mounted on a 2½-ton, 6 by 6 cargo truck, with a 1-ton trailer on which a portable field powered unit is installed.
AN/GRC-46	80	1.5-20.0 rcvr .5-32.0.	AM	Voice CW RATT.	Same as GRC-19, with radio-teletype facilities. Mounted in ¾-ton truck.
AN/GRC-106	80	2-30	AM	Voice CW RATT SSB.	Command net. Used by all engineer units down to company headquarters.
AN/GRC-122	80	2-29.99	AM	Voice CW RATT.	Replaces AN/GRC-46.
AN/GRC-125	5-8	30-75.95	FM	Voice	Combination vehicular/man pack version of AN/PRC-25. Used by battalion.
AN/GRC-142	80	2.000-29.999	AM	Voice CW RATT SSB.	Replaces AN/GRC-46. Used for command, operations, and intelligence nets.

Table 3-2. Characteristics of Radios Organic to Engineer Units—Continued

Radio set	Operating range (km)	Frequency range (MHz)	Modulation	Emission	Remarks
AN/GRC-160	5-8	30-75.95	FM	Voice	Combination vehicular/man pack version of the AN/PRC-77. Used in company and battalion. Adaptable with security device.
AN/PRC-25	5-8	30-75.95	FM	Voice	Portable transistorized set. Used at squad level or for utility set for dismounted operations.
AN/PRC-74	40	2-18.0	AM	Voice CW.	Portable SSB with voice and CW capability to provide man pack operation when line of sight is not available.
AN/PRC-77	5-8	30-75.95	FM	Voice	Modified version of AN/PRC-25. Modified to accept a security device and to allow it to be operated in the same vehicle as a radio of the AN/VRC-12 series.
AN/PRC-88	1.6	47-57	FM	Voice	Helmet receiver and hand transmitter. Replaces PRC-6.
AN/VRC-12	25-32	30-75.95	FM	Voice	Same capability and use as AN/VRC-47, but has automatic frequency selection.
AN/VRC-24	48	225-399.9	AM	Voice	Used to communicate with aircraft in close support of ground operations.
AN/VRC-43	25-32	30-75.95	FM	Voice	Same capability and use as AN/VRC-46, but has automatic frequency selection.
AN/VRC-44	25-32	30-75.95	FM	Voice	Same capability and use as AN/VRC-48, but has automatic frequency selection.
AN/VRC-45	25-32	30-75.95	FM	Voice	Same capability and use as AN/VRC-49, but has automatic frequency selection.
AN/VRC-46	25-32	30-75.95	FM	Voice	Single receiver/transmitter. Used at company and platoon level to work in only one net. Also used by battalion and higher staff.
AN/VRC-47	25-32	30-75.95	FM	Voice	Single receiver/transmitter plus an auxiliary receiver. Used at company and higher level to work in one net while monitoring another.
AN/VRC-48	25-32	30-75.95	FM	Voice	Same capability and use as AN/VRC-47, but has one additional auxiliary receiver.
AN/VRC-49	25-32	30-75.95	FM	Voice	Two receiver/transmitters. Works in two nets. Used by engineer units in the combat zone as a radio relay.
AN/VRC-53	5-8	30-75.95	FM	Voice	Vehicular version of AN/PRC-25. Used in units when a short range, vehicular radio is required.
AN/ARC-51	48	225-399.9	AM	Voice	Provide communication between aircraft, from air to ground, and from ground to ground.

Table 3-2. Characteristics of Radios Organic to Engineer Units—Continued

Radio set	Operating range (km)	Frequency range (MHz)	Modulation	Emission	Remarks
AN/ARC-54	54	30-69.95	FM	Voice	Used in army aircraft for communication between aircraft or between aircraft and ground.
AN/ARC-102	Extended	2.000-29.999	AM	CW DSB	Installed in army aircraft for air-ground communication.
AN/SRC-6	55	0.5-8.28	AM	Voice Automatic Continuous Tone.	Portable lifeboat radio set (Team HI, TOE 5-530)
AN/SRC-8	60	2-3.5	AM	Voice	Provides 2-way, ship-to-shore and ship-to-ship radio service for ships in coastal waters. (Team HI, TOE 5-530).
AN/URC-10	55	240-260	AM	Voice Automatic Continuous Tone.	Emergency rescue radio set. Carried by aircraft crew members or in survival kit.
AN/VSC-2	80	2.000-29.999	AM	Voice CW RATT SSB.	Replaces AN/VSC-1. Used in airborne/airmobile units for command, operations, and short range vehicular radio as required.
AN/TRC-135	25-32	30-70	FM	Voice	Authorized only in HHC, Engr Bn, Airmobile Div. Two receiver/transmitters and one auxiliary receiver. Works in two nets while monitoring a third.

Legend

SSB—Single-side band
 DSB—Double-side band
 CW—Continuous wave
 RATT—Radio Teletypewriter
 AM—Amplitude modulated
 FM—Frequency modulated
 MHz—Megahertz

b. (1) The AN/VRC-12 family of radios is designed for vehicular operation and is replacing the old AN/GRC-3 through 8 series in all combat arms. Eight different set configurations are possible by combining subunits of the radio. These common subunits are as follows:

- (a) Automatic tune receiver-transmitter. (For use in Armor vehicles).
- (b) Manual tune receiver-transmitter. (General use).
- (c) Auxiliary receiver.
- (d) Mount.
- (e) Antenna.
- (f) Installation kits as authorized for vehicular installation and intercommunication.

(2) Comparison of the AN/VRC-12 Family to the AN/GRC-3 through 8 series.

- (a) Lighter weight and smaller size.
- (b) Common frequency spectrum for all combat arms.
- (c) Accept speech security device.
- (d) Automatic squelch control.
- (e) Visual incoming signal (call light).
- (f) Increased transmitting range.
- (g) Automatically tuned antenna.
- (h) Module construction for ease of maintenance.
- (i) Compatibility with AN/GRC-3 through 8 series, except Armor band (20-30 MHz).

Section II. POL

3-3. Fuels, Lubricants, Fluids, and Antifreeze for Equipment

a. Fuels, lubricants, and hydraulic fluids are issued for engineer equipment, depending on ambient conditions.

b. Two types of antifreeze are issued. Ethylene glycol is normally issued when temperatures from 32° F to -25° F are anticipated. This is mixed with the engine coolant in varying proportions. Arctic antifreeze normally is issued for anticipated temperatures under -25° F. Arctic antifreeze is premixed and does not permit addition of water.

c. In addition to these two antifreeze materials it is common practice to add denatured alcohol to engine and heater fuel tanks when subfreezing temperatures are encountered. Normally it is added in a ratio of 1 quart of alcohol to 30-50 gallons of gasoline.

d. In addition to the above it is necessary to provide special winterization to standard equipment for operations in extremely low temperatures. Items such as special fan belts, hose, engine preheaters, and personnel heaters are required.

e. Items in a above available to engineer troop units, are listed in table 3-3.

Table 3-3. Stock Military Fuels, Lubricants, Fluids, and Antifreezes for Engineer Equipment

Product	Federal Stock No.	Container Size	Specification	Grade
Fuel oil, diesel, regular	9140-286-5296	55 gal	Mil-F-16884	F-75
Fuel oil, diesel, winter grade	9140-286-5288	55 gal	VV-F-800	DF-A
Fuel oil, diesel, arctic grade	9140-286-5284	55 gal	VV-F-800	DF-2
Gasoline, auto, combat (general)	9130-221-0680	55 gal	Mil-G-3056, Type II	
Gasoline, auto, combat (low temp)	9130-221-0685	55 gal	VV-G76	Premium
Lubr. oil, int. comb. eng.	9150-265-9435	5 gal	Mil-L-2104	OE30
Lubr. oil, int. comb. eng., subzero	9150-242-7603	5 gal	Mil-L-10295	OES
Lubr. oil, gear, grade 90	9150-577-5846	55 gal	Mil-L-10324	GOS
Lubr. oil, rock drill	9150-142-9320	55 gal		
Greases:				
Aircraft and instrument (for sealed bearings) low temp	9150-985-7243 7246			
Automotive and artillery (for chassis elements)	9150-190-0907	35 lb	Mil-G-10924	GAA
Priming fluids:				
Pressure primer, cartridge	2910-355-6377			
Starter fluid, internal combustion engine	6850-823-7861	12 oz		
Hydraulic fluid, non-petr. (brake system)	9150-231-9071	1 gal	VV-H-910	
Hydraulic fluid, non-petr. arctic type (brake system)	9150-252-6375	1 gal	Mil-H-13910	
Hydraulic fluid, petr. base	9150-233-4134	1 gal	Mil-O-6083	
Lubr. oil, instrument	9150-223-4129	1 qt		
Antifreeze, ethylene-glycol type	6850-243-1992	1 gal		
Antifreeze, arctic type	6850-174-1806	55 gal	Mil-L-C11755	
Alcohol, denatured, grade III		1 gal		

3-4. Fuel Consumption

a. Fuel consumption figures should only be used in computing general requirements data. Some of the factors influencing petroleum consumption are as follows:

(1) Cross-country movement is estimated at

two and one-half times the consumption over roads.

(2) For arctic winter operations, increase all basic amounts by 25 percent.

(3) To cover such items as spillage, evaporation, and small combat losses, an additional

10 percent of the total consumption figure should be included in the estimation.

(4) An experienced vehicle or equipment operator will, as a general rule, use less petroleum products than an inexperienced person.

(5) The newness and condition of the vehicles and equipment will have a bearing on the estimated amounts of petroleum products required, and should be considered.

(6) The movement of vehicles and equip-

ment within bivouac areas and on reconnaissance, the warming up of engines, and abnormal periods of low-gear operation must be considered when estimating petroleum requirements.

(7) Additional daily requirements exist for administrative vehicles, gasoline-powered equipment, and maintenance and testing of engines.

b. Table 3-4 shows fuel consumption rate per 100 vehicles or pieces of equipment.

Table 3-4. Fuel Consumption Rates/100 units

	Gasoline	Diesel
Auger, earth, truck mtd	000300 ²	
Compressor, air, 3 stages 15 CFM, GED	000062 ²	
Compressor, air, 125 CFM	000322 ²	
Compressor, air, 250 CFM		000562 ²
Compressor, air, 600 CFM		000700 ²
Crane, Whl, Mtd: 5 Ton $\frac{3}{4}$ cu yd 4x4 Rough Terrain		000350 ²
Crane, Whl, Mtd: 20 Ton $\frac{3}{4}$ cu yd Rough Terrain		000350 ²
Crane-Shovel Crwlr Mtd: 10 Ton $\frac{3}{4}$ cu yd	000420 ²	
Crane-Shovel Crwlr Mtd: 12 $\frac{1}{2}$ Ton $\frac{3}{4}$ cu yd **		
Crane-Shovel Crwlr Mtd: 40 Ton 2 cu yd		000850 ²
Crane, Whl Mtd: 7 Ton w/boom crane 24 ft	000275 ²	
Crane-Shovel Trk, Mtd: 20 Ton $\frac{3}{4}$ cu yd	000400 ²	
Crushing and Screening Plant: DSL and ELEC 75 TPH		000740 ²
Crusher Jaw: Whl, Mtd 15 TPH	000460 ²	
Distributor Bitumen Material Tank Type 800 Gal	000050 ¹	000160 ²
Distributor Water Tank Type 1000 Gal	000080 ¹	000160 ²
Ditching Machine: Whl, Mtd Ladder		000450 ²
Drier-Mixer Bitumen-Concrete Whl, Mtd: 3 TPH	000250 ²	
Drilling Machine, Well: 6 in Dia at 1000 Ft	000275 ²	
Firefighting Equip Set: Trk Mtd	000800 ²	
Generator DED: 15 KW 60 cy 3 PH AC 120/208 240/416		000350 ²
Generator DED: 45 KW 60 cy 3 PH AC 120/208 240/416		000500 ²
Generator DED: 30 KW 60 cy 3 PH AC 120/208 240/416		000420 ²
Generator DED: 45 KW 400 cy 3 PH AC 120/208 240/416		000500 ²
Generator DED: 60 KW 60 cy 3 PH AC 120/208 240/416 50 cy		000600 ²
Generator DED: 100 KW 60 cy 3 PH AC 120/208 240/416 50 cy		000800 ²
Grader Road Motorized: Airtransportable 6x4		000460 ²
Grader Road Motorized: 6x4		000560 ²
Hammer Pile Driver Self-powered: 7500 FT LB		000250 ²
Hammer Pile Driver Self-powered: 22,400 FT LB		000730 ²
Kettle Heating Bitumen: Trlr Mtd 165 Gal	000125 ²	
Kettle Heating Bitumen: Skd Mtd 750 Gal	000275 ²	
Loader Scoop Type: 4 whls 1 $\frac{1}{2}$ cu yd		000400 ²
Loader Scoop Type: 4 whls 2 $\frac{1}{2}$ cu yd		000590 ²
Lubricator-Service Unit: 15 CFM Air Comp	000200 ²	
Mixer Concrete Trailer Mounted: GED 16 cu ft	000125 ²	
Mixer Rotary Tiller: Self-Propelled		000275 ²
Paving Machine Bituminous Material: Crwlr Mtd 12 ft RN.	000275 ²	
Pump Centrifugal: 125 GPM 50 FT HD	000030 ²	
Pump Centrifugal: 500 GPM 30 FT HD	000050 ²	
Pump Centrifugal: 1500 GPM 60 FT HD	000075 ²	
Pump Reciprocating: 100 GPM 10 Suction Lift	000048 ²	
Roller, Motorized: 5-8 Tons	000275 ²	
Roller, Motorized: 3 Whl 10 Ton w/sprinkler	000375 ²	
Saw Chain: 18 in	000100 ²	
Shop Equipment Contact Maint Trk	000400 ²	
Shop Equipment General Purpose Repair	000475 ²	

See notes below table.

Table 3-4. Fuel Consumption Rates—Continued

	Gasoline	Diesel
Tractor Full Tracked Low Speed: Heavy		000800 ²
Tractor Full Tracked Low Speed: Light		000430 ²
Tractor Full Tracked Low Speed: Medium		000970 ²
Tractor Whld Industrial: MED-DBP		001470 ²
Tractor Whld Industrial: Light-DBP		000690 ²
Tractor Whld Industrial: Cat-830		001200 ²
Truck Ambulance: ¾ Ton 4x4 w/E	000010 ¹	
Truck Ambulance: 1¼ Ton 4x4 w/E	000010 ¹	
Truck Cargo: ¾ Ton 4x4 w/E	000010 ¹	
Truck Cargo: 1¼ Ton 4x4 w/E	000012 ¹	
Truck Cargo: 2½ Ton 6x6 w/E	000025 ¹	
Truck Cargo: 5 Ton 6x6 LWB w/E	000036 ¹	
Truck Cargo: 10 Ton 6x6 w/Winch w/E	000033 ¹	
Truck Contact Maint: ¾ Ton	000012 ¹	
Truck Dump: 5 Ton 6x6 w/Winch w/E	000023 ¹	
Truck Lift Fork: DED 6000 lb Cap		000555 ²
Truck Lift Fork: DED 10,000 lb Cap		000650 ²
Truck Lift Fork: GED 6000 lb Cap Rough Terrain	000500 ²	
Truck Lift Fork: GED 10,000 lb Cap Rough Terrain	000600 ²	
Truck Tank: Water 1000 gallon 2½ Ton 6x6 w/Winch w/E.	000021 ¹	
Truck Tractor: 5 Ton 6x6 w/E	000036 ¹	
Truck Utility: ¾ Ton 4x4 w/E	000006 ¹	
Truck Van: Shop 2½ Ton 6x6 w/E	000015 ¹	
Truck Wrecker: 5 Ton 6x6 w/Winch w/E	000036 ¹	
Water Purif, Equip: Trlr Mtd Diatomite Filter 600 GPH000	000250 ²	
Water Purif, Equip Set: Trk Mtd Diatomite Filter 1500 GPH	000250 ²	
Water Purif, Equip Set: Trk Mtd Diatomite Filter 3000 GPH	000250 ²	
Welding Machine Arc: 300 Amp DC Skd Mtd	000200 ²	

¹ Shows gallons of fuel requirement to operate equipment one mile.² Shows gallons of fuel requirement to operate one hour.³ Shows gallons of fuel requirement to operate auxiliary equipment one hour.⁴ Per 100 vehicles or pieces of equipment.

**Consumption data not available at time of publication.

Section III. REPAIR PARTS

3-5. Identification of Equipment Repair Parts

Master Cross Reference Lists are prepared to provide the Army cross reference information to Federal Stock Numbers when the manufacturers reference number and code is the only information available. The data contained in Master Cross Reference List, C-RL-1-A, are as follows:

a. Reference Number. A number other than an activity stock number, used to identify an item of production or, either by itself or in conjunction with other reference numbers, to identify an item of supply. Reference numbers included are manufacturers' part, drawing, model, type, source controlling numbers, specification controlling numbers and the manufacturer's trade name when the manufacturer identifies the item by trade name only; specification or standard part, drawing, or type numbers.

b. Federal Supply Code for Manufacturers

(FSCM). The applicable manufacturers' assigned five-digit code, as listed in Cataloging Handbook H4-2, "Federal Supply Code for Manufacturers" (Code to Name).

c. Reference Number Variation Code (RNV). The code indicates whether the reference number is item identifying or requires additional data to correctly identify the item of supply, or is associated with a source or specification control drawing: i.e.

Code 1—Nonidentifying

Code 2—Identifying

Code 3—Source or specification control drawing association

d. Federal Stock Number (FSN). The FSN for an item of supply is uniformly eleven digits consisting of the applicable four-digit Federal Supply Class Code plus the seven-digit Federal Item Identification Number (FIIN).

3-6. Index Guide

A guide for use of the Master Cross Reference List is shown in table 3-5.

3-7. Excluded Items

An index of all volumes and coverage of each volume is published on the first page of each volume of the Master Cross Reference List. The first and last reference number contained in each volume is printed on the cover.

3-8. Master Cross Reference List

Reference numbers such as NATO Stock Numbers, Military Supply Standard Numbers, Peculiar Equipment Codes, DOD Ammunition Codes and NATO reproduced item reference numbers are not included in the Master Cross Reference List.

3-9. Numbering System

Numbering system for the Master Cross Reference List is as follows:

Reference No.	Mfr Code	RN VC	Federal Stock No.	Reference No.	Mfr Code	RN VC	Federal Stock No.
MS90723-7	96906	2	5310-575-5492	MT139A1	92825	2	5940-543-8414
MS90725-132	96906	2	5305-716-8203	MT1762AR	80058	2	5826-506-4474
MS90725-135	96906	2	5305-716-8206	MT17951-050-416	76561	2	5975-087-1698
MS90725-150	96906	2	5305-716-8195	MT18PB	00348	2	5950-879-9297
MS90725-155	96906	2	5305-724-5905	MT326822-881	40171	2	3110-101-7440
MS90725-156	96906	2	5305-724-5906	MT345	65586	2	4540-859-5777
MS90725-157	96906	2	5305-724-5907	MT3624TSC38B	80058	2	5895-926-2921
MS90725-171	96906	2	5305-724-5937	MT3969ASH329	80058	2	4920-879-6548
MS90726-154	96906	2	5305-724-6802	MT3985TRC24	80058	2	5985-054-4302
MS90726-159	96906	2	5305-725-4097	MT3986ASH339V	80058	2	6605-782-0279
MS90726-161	96906	2	5305-725-4100	MT3987ASH339V	80058	2	6605-782-0278
MS90726-175	96906	2	5305-725-4166	MT4310P	43990	2	3110-155-6744
MS90726-185	96906	2	5305-727-8810	MT51102C501213	00000	2	5330-196-5381
MS90726-199	96906	2	5305-728-0216	MT51102C501218	00000	2	5330-260-9311
MS90726-201	96906	2	5305-727-8830	MT600MPD55VDC	00853	2	5910-863-1758
MS90727-103	96906	2	5305-709-8284	MT600AAPR9	80058	2	5975-224-6941
MS90727-120	96906	2	5305-719-5244	MT607APR9	80058	2	5975-224-6941
MS90727-122	96906	2	5305-719-5269	MT72	26051	2	5306-733-9404
MS90727-156	96906	2	5305-726-2516	MT821ARC27	80063	2	5820-69-6679
MS90727-158	96906	2	5305-726-2525	MT847	39317	2	3110-084-3472
MS90727-159	96906	2	5305-726-2533	MT865GR	80058	2	5825-030-2964
MS90727-165	96906	2	5305-726-2552	MT982	92567	2	3110-084-3481
MS90727-173	96906	2	5305-726-2560	MUC1205-15REV10	51600	3	3110-727-7107
MS90727-174	96906	2	5305-726-2561	MUC4D288-409	66289	2	2805-871-6690
MS90727-175	96906	2	5305-726-2562	MUS220	17708	2	6625-519-2629
MS90727-176	96906	2	5305-726-2567	MUOB1-1-2	21305	2	3110-108-4541
MS90727-178	96906	2	5305-726-2572	MVP4-SPEC298206	66289	2	2805-871-6689
MS90727-71	96906	2	5305-269-3247	MVTAD157618	66289	2	2805-656-6824
MS90727-91	96906	2	5305-709-8542	MTL6-2M	27801	2	5910-878-6415
MS90727-96	96906	2	5305-709-8482	MVM63919	98625	3	5815-089-8021
MS90727-97	96906	2	5305-709-8423	MVT89029A1S1863V	8725	2	5310-886-5744

ALPHA-NUMERIC
SEQUENCE

REFERENCE NUMBER
IS SELF-IDENTIFYING

SANGAMO ELECTRIC CO
PERKINS DIVISION
PERKINS, SOUTH CAROLINA

FEDERAL STOCK NUMBER FOR
REQUISITIONING STOCKING
STORING AND ISSUING

NOTE: MCRL CONTAINS A FOUR COLUMN FORMAT.
TWO COLUMN FORMAT FOR USAGE GUIDE PURPOSE ONLY

Table 3-5. RL Usage Guide

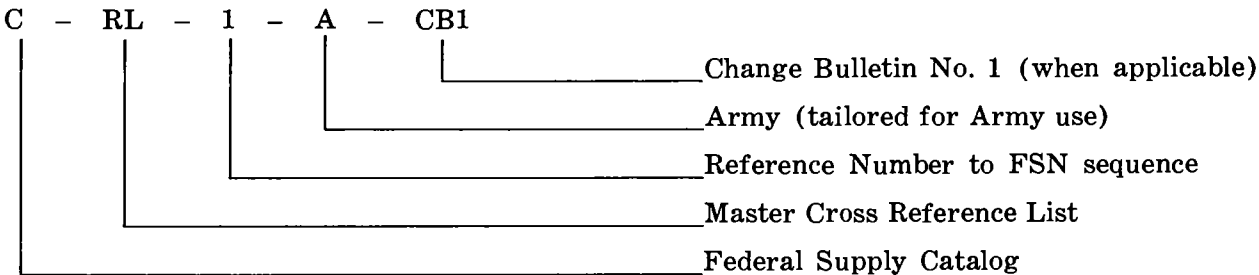
a. The first segment of the catalog number is the uppercase letter "C" which denotes a Federal Supply Catalog publication.

b. The second segment of the catalog number is the uppercase letters "RL" which identify the catalog as a Master Cross Reference List.

c. The third segment of the catalog number is a numeric "1" to designate the "RL" as published in Reference Number to FSN sequence. The third segment shall be suffixed with the uppercase letter "A" to reflect it as a tailored publica-

tion for the Army and contains all Army used or managed items with an Army user recorded in the Defense Logistics Services Center files with an Inventory Manager Responsibility Code other than "O".

d. The fourth segment of the catalog number, when applicable, shall be composed of the letters "CB" to identify a Change Bulletin. The number of the Change Bulletin will also be included, e.g., C-RL-1-A-CB1, indicating Change Bulletin Number 1 applicable to Federal Supply Catalog C-RL-1-A. Example of the above is as follows:



Note. A Master Cross Reference List (FSN to Reference Number Sequence) is not compiled for Army items.

3-10. Maintenance

The Master Cross Reference List will be revised

annually and maintained current by issuance of cumulative Change Bulletins on a quarterly basis.

Section IV. SPECIAL DATA

3-11. Aircraft Available for Moving Equipment Common to Engineer TOE Units

The aircraft for which requirements have been developed are military cargo aircraft. Data shown in table 3-6, under the columnar heading C-130, C-141, C-124, C-133, and C-5A represent the aircraft that can accommodate at least one of the

various items of equipment. These data are based upon size of door openings, cargo load, and square feet capacities of the various planes. However, there are other factors which will ultimately determine the aircraft load, such as judgment of the commander, range of mission, runway length, airport elevation, temperature, and other considerations peculiar to this mode of transportation.

Table 3-6. Weight, Cubage, and Aircraft Data for Moving Large Equipment, Common to Engineer TOE Units

TOE Lin	FSN	Description	Model number	Length (in.)	Reduced width (in.)	Dimensions height (in.)	Cube (ft ³)	Net weight (lb)	C-130	C-141	Aircraft C-124	C-133	C-5A
C03283	3815-752-9022 2 pcs lgst 196.5x32x29.8	Boom crane 30 ft	M200 202	196.5	45.0	45.0	230.3	2380	X	X	X	X	X
C04653	3815-197-7283	Boom ext mid 1 ft	22B	120.0	28.0	26.0	50.6	480	X	X	X	X	X
C29490	3815-378-8682	Bkt clmshl ¾ cu yd	ERIE-X02	71.5	38.0	76.8	120.8	3600	X	X	X	X	X
C18481		Breaker pav dr sk	SINKER	112.0	72.0	30.0	140.0	2500	X	X	X	X	X
C29353	3815-272-8673	Bkt clmshl ½ cu yd	TY335-5	68.5	29.0	77.0	88.5	3220	X	X	X	X	X
C30860	3815-585-2694	Bkt dragline ½ yd	AX	60.6	39.5	44.8	62.1	1300	X	X	X	X	X
F39172		Crane wheel mtd 3T		213.0	108.0	105.0	1397.8	21000			X	X	X
F39378	3810-763-7728	Crane rough/t 20T	2380	343.5	126.5	149.0	3746.8	58582					X
F39378	3810-763-7728A	Boom point sec	2380	192.5	32.3	30.5	109.7	1240	X	X	X	X	X
F39378	3810-763-7728B	Boom foot sec	2380	183.0	40.6	30.5	131.1	1000	X	X	X	X	X
F43077	3810-818-3381	Cr-shvl whlmtd 7T	155-1A	203.3	101.8	88.5	1059.9	15470	X	X	X	X	X
F50995	3820-641-4968	Crusher jaw whlmtd	AB1424SP	223.0	79.5	92.3	947.0	16000	X	X	X	X	X
G02478	6665-912-1846	Det st mine trkmtd	324	167.3	78.3	81.5	617.8	3500	X	X	X	X	X
G28212	3825-629-5901	Distr wtrtk trkmtd	W1M5	303.0	97.5	104.0	1778.0	21550			X	X	X
G27664	3895-690-8289	Distr bitum trkmtd	MXRED 30	325.5	97.0	103.0	1882.0	24760		X	X	X	X
G34815		Dolly set lift	M689	118.0	96.0	60.5	396.6	3500	X	X	X	X	X
J49398	6115-504-0846 Skid mtd	Gen set skmtd 10kw	GGC 10 AC 2	68.0	28.0	48.3	53.2	1600	X	X	X	X	X
J74852	3805-931-7881	Grader rd mtz ded	440HA	307.3	92.3	93.5	1534.7	26990		X	X	X	X
J74886		Grader rd mtz ded	MDL 112	270.0	91.0	80.0	1137.5	16000	X	X	X	X	X
J76489		Grass ctr air mbl	CY-60	144.0	60.0	40.0	200.0	2000	X	X	X	X	X
K20417		Hayrake air mbl		160.0	96.0	60.0	533.3	3500	X	X	X	X	X
K04697	3895-014-0583 3 pcs lgst 137x25x23.8	Hammer piledvr dsl	180M	137.0	26.8	26.8	56.9	5770	X	X	X	X	X
L21300	3895-710-7620	Kettle bitm skdmtd	750-US	164.8	87.5	57.0	475.7	5850	X	X	X	X	X
L21437	3895-066-6015	Kettle bitm tirmtd	US84HD3	144.0	67.3	56.0	314.1	1830	X	X	X	X	X
L49089	3815-983-8029	Lead sec top p dvr	15 FT	189.0	38.3	28.3	118.6	1200	X	X	X	X	X
L76351	3805-761-1640	Loader scp-ty whld	H-60	234.8	97.5	93.0	1232.1	17860	X	X	X	X	X
L76556	3805-051-9359	Loader scoop type	645M	282.3	101.3	99.0	1638.4	24825		X	X	X	X
L76625	3805-866-3849	Loader scp-ty whld	175A-M23	258.5	107.3	99.0	1589.1	29980		X	X	X	X
L76693		Loader scy-ty sec	TL-645	131.0	69.0	75.0	392.3	6000	X	X	X	X	X
L85420		Lub svc unit tlrmtd	WZTD	174.3	97.5	80.0	786.8	5330	X	X	X	X	X
M54151	3895-835-4512	Mixer conc tlrmtd	HBG	105.0	93.8	128.5	732.4	6220			X	X	X
M76101	4910-675-1478	Mounter pneu tire	LEE-1	66.5	34.5	57.0	75.7	1000	X	X	X	X	X
P11866	3820-950-8584	pneu tl+cmp tlrmtd	RPV250	214.0	97.0	75.3	904.6	8910	X	X	X	X	X
Q34906	5820-248-3508	Radio set	AN/GRR-5	190.3	82.5	70.6	641.4	5800	X	X	X	X	X
S11616	3895-965-0072	Roller mtz 3 whl	E-1012-M	224.5	76.3	80.5	798.0	21340	X	X	X	X	X

Table 3-6. Weight, Cubage, and Aircraft Data for Moving Large Equipment, Common to Engineer TOE Units—Continued

TOE Lin	FSN	Description	Model number	Length (in.)	Reduced width (in.)	Dimensions height (in.)	Cube (ft ³)	Net weight (lb)	C-130	C-141	Aircraft C-124	C-133	C-5A
S11684	3895-902-3111	Roller mtz 9 whl	SP54B	160.5	72.0	72.0	481.5	7900	X	X	X	X	X
S12164	3895-641-6475	Roller twd 13 tire	R67S	122.5	88.5	46.0	288.6	4100	X	X	X	X	X
S12438	3895-033-4986	Roller twd 4 tire	RT-100CE	294.5	95.5	92.0	1497.4	14710	X	X	X	X	X
S12575	3895-241-3542	Roller twd sheepft	MD 96	152.0	118.0	53.5	555.3	7500		X	X	X	X
S56119		Scraper airmbl sec		144.0	96.0	90.0	720.0	16000	X	X	X	X	X
S5626	3805-069-3316	Scraper twd whlmt d	58SH-G	372.5	125.5	123.0	3327.6	33500				X	X
S56941	3805-811-7671	Scraper twd whlmt d	AR775	334.0	99.3	81.8	1570.0	12675	X	X	X	X	X
S70517	2330-317-6448	Stir low-bed 25 ton	M172A1	415.5	115.0	66.5	1838.9	16285		X	X	X	X
T13152	4940-294-9516	Shop eq org trkmt d	5TON TRK	362.8	98.3	124.3	2565.4	32780				X	X
T16988	3220-270-8630	Shop eq wwk tlrmt d	EQWWBMTM	171.5	84.8	81.3	684.2	5680	X	X	X	X	X
T40634	3815-641-7478	Shvl front cr/shvl	M20B/20A	256.8	39.5	69.0	405.0	7540	X	X	X	X	X
U12063	3895-679-5759	Spreader aggr twd	C8M1	99.3	74.0	70.5	299.8	2630	X	X	X	X	X
V12141	4930-542-2800	Tank + pump unit liq	115-1	72.0	91.5	91.5	348.8	1700	X	X	X	X	X
W50486	5180-289-9569	Tool outfit ptbl	PIONEER	147.3	74.5	73.0	463.6	2180	X	X	X	X	X
W76200		Tractor air mobile	4 x 4	195.0	100.0	80.0	902.8	16000	X	X	X	X	X
W76268		Tractor air mobile	SECT	220.0	135.0	120.0	2062.5	45000					X
W76302		Tractor air mobile		200.0	105.0	84.0	1020.8	24000	X	X	X	X	X
W76336	2410-935-0714	Trac F trac ls ded	M450	142.0	88.0	65.5	473.7	9910	X	X	X	X	X
W76816	2410-078-6483	Trac F trac ls ded	HD 16M	201.8	121.5	93.3	1323.8	44140		X		X	X
W76816	2410-078-6483A	Dzr blde 1 ea	HD 16M	135.0	30.0	50.6	118.6	7000	X	X	X	X	X
W76816	2410-078-64838	Dzr arm w/tilt cyl	HD 16M	128.3	26.0	12.8	24.7	1000	X	X	X	X	X
W83529	2410-926-3697	Trac F trac ls ded	D7E	252.5	114.5	94.0	1572.7	43994		X		X	X
W83529	2410-926-3697A	Dzr bld 1 ea		133.0	39.3	44.5	134.6	7010	X	X	X	X	X
W83529	2410-926-3697B	Dzr arm w/tilt cyl		126.0	26.8	11.0	21.5	1060	X	X	X	X	X
W90790	2420-088-9384	Trac whld ind ded	MDL 290M	326.5	135.8	122.8	3150.9	54500					X
W94441	2330-697-8102	Tir basic utility	T52	184.5	96.3	44.0	452.4	2600	X	X	X	X	X
W95400	2330-706-5495	Tir cargo ¼ ton	M416	108.5	61.5	44.0	169.9	580	X	X	X	X	X
W95537	2330-898-6779	Tir cargo ¾ ton	M101A1	147.0	73.5	50.0	312.6	1350	X	X	X	X	X
W95811	2330-141-8050	Tir cargo 1½ ton	M105A2	166.0	83.0	55.0	438.5	2670	X	X	X	X	X
W96907	2330-255-9190	Tir flat bed lot	CTP-7F	338.3	97.8	63.5	1215.8	11930	X	X	X	X	X
W98825	2330-542-2039	Tir tk wtr 400 gal	M149	161.5	80.8	79.8	602.6	2840	X	X	X	X	X
X38639	2310-835-8686	Truck amb ¼ ton	M170	155.0	60.5	56.3	305.5	2963	X	X	X	X	X
X39735	2320-542-4636	Truck cargo ¾ ton	M3781	185.5	75.3	64.5	521.4	5660	X	X	X	X	X
X40009	2320-077-1616	Trk cargo 2½ ton	M35A2	264.8	96.5	81.3	1202.2	13060	X	X	X	X	X
X40146	2320-077-1617	Trk cargo 2½ ton	M35A2WWN	278.5	96.5	81.3	1264.4	13700	X	X	X	X	X
X40420	2320-077-1619	Trk cargo 2½ ton	M36A2WWN	342.5	95.0	80.5	1515.8	15110	X	X	X	X	X

X43228	2320-911-5071	Trk dump ¾ ton	XM708	190.0	75.3	64.5	534.0	7487	X	X	X	X	X
X43297	2320-077-1643	Trk dump 2½ ton	M342A2	260.3	95.3	80.8	1159.9	15230	X	X	X	X	X
X43434	2320-077-1644	Trk dump 2½ ton	M342A2WW	276.0	95.3	80.8	1229.9	16165	X	X	X	X	X
X43706	2320-055-9262	Trk dump 5 ton	M51A2	266.0	97.8	86.0	1294.7	22560	X	X	X	X	X
X43845	2320-055-9263	Trk dump 5 ton	M51A2WWN	281.5	97.8	86.0	1370.7	22860	X	X	X	X	X
X48914	3930-937-0220	Trk lft frk 6000 lb	MLT-6CH	187.3	103.3	105.3	1179.0	23000			X	X	X
X52818	3930-950-9985	Trk lft frk 3000 lb	ART-30	134.0	76.3	72.0	426.0	3400	X	X	X	X	X
X57408	2320-440-3346	Trk tk fs 2½ ton	M49A1CWW	276.5	96.0	89.0	1367.1	15190	X	X	X	X	X
X59326	2320-055-9260	Trk tractor 5 ton	M52A2	258.3	98.3	85.3	1253.4	18560	X	X	X	X	X
X59874	2320-226-6081	Trk tractor 10 ton	M123A1C	289.0	114.8	91.3	1752.9	29658		X	X	X	X
X60833	2320-763-1092	Trk utility ¼ ton	M151A1	132.5	63.5	52.8	257.1	2380	X	X	X	X	X
X63299	2320-055-9258	Trk wrecker 5 ton	M543A2WW	349.0	98.0	107.3	2123.8	34884				X	X
X63094	2320-911-5068	Trk wrecker ¾ ton	XM711	215.5	76.3	94.5	899.2	7520	X	X	X	X	X
Y35486	4610-202-6925	Wtr plr trkmtd wwn	1500 GPH	.0	.0	.0	.0	0	X	X	X	X	X
Y35486	4610-202-6925A	Trk van red		280.5	99.8	126.5	2049.3	18940			X	X	X
Y48255	3431-287-5404	Welding shop tlrmtd	300AMP	166.0	83.0	83.0	661.8	5845	X	X	X	X	X

3-12. Logistics of Prefabricated Buildings

Logistics of prefabricated buildings are given in table 3-7.

3-13. Weapons

Table 3-8 gives the nomenclature, cubages and weight of weapons common to engineer units.

Table 3-7. Prefabricated Buildings

Type of building	Size (feet)	Shipping data	
		Number of packages	Measurement tons
Quonset buildings (Great Lakes Steel) -----	40 x 100	20	9.6
Metal, rigid frame (Butler) -----	40 x 100	22	12.2
Butlerhut (A-frame, Metal) -----	20 x 48 x 6.83	18 with floor 14 without floor.	9.9 7.3
Steel or aluminum barracks (insulated) -----	20 x 50 x 8	-----	8.2
Steel or aluminum warehouse (uninsulated) -----	40 x 100	-----	32.9
Steel or aluminum shop (uninsulated) -----	40 x 100	-----	30.0
Arch steel general purpose (insulated) -----	20 x 48	-----	12.7
Arctic wood panel (insulated and heated) -----	20 x 48	-----	25.0
Pascoe* -----	20 x 48 x 6.83	-----	-----

*Prefabricated metal lean-to that can be easily expanded to 40' x 100' x 9'.

Table 3-8. Weapons Common to Engineer Units

Nomenclature	Units per package	Weight (lb)	Cubic foot	Package dimensions (ft)		
				L	W	H
Rifle 7.62 MM M14 -----	1	13	.460	3.75	.50	.25
Rifle 7.62 MM: automatic with bipod M14A1.	1	21	1.237	3.94	.94	.33
Pistol caliber .45 automatic M1911A1 ..	1	4	.166	.92	.54	.33
Machinegun 7.62 MM: light flexible M60.	1	53	2.812	1.09	.91	2.90
Rocket HE 66MM -----	15					
Grenade launcher -----	1	9	.608	2.58	.62	.38
Rifle 5.56MM M16A1 -----	2	23	.692	3.29	.75	.24
Rifle 5.56MM M16A1 ¹ -----	40	562	40.2	3.73	3.48	3.19

¹ M16A1 gross shipped in 20 carton modules.

3-14. Gases and Gas Cylinders

a. *Characteristics.* The characteristics of certain gases which are used in industry and in the Army, and which are stored and shipped in a compressed state, are shown in table 3-9.

b. U. S. and Foreign Cylinders.

(1) In the United States, cylinders for compressed gases are manufactured under various Department of Transportation (DOT) (formerly ICC) specifications. For details see AR 700-68.

(2) The use of color coding for compressed-gas cylinders is mandatory. The exact identification of any material contained in a compressed-

gas cylinder is *also mandatory* and shall be made ONLY by means of the written title, as shown in figure 3-1. Figure 3-1 also shows the locations of identifying colors on bottle type cylinders as specified in Mil-Std-101-A, and change I to Mil-Std-101-A.

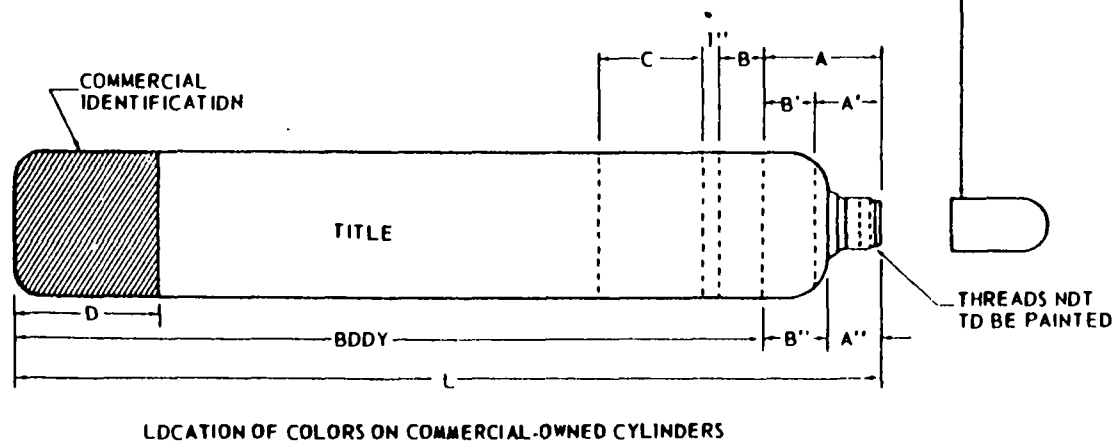
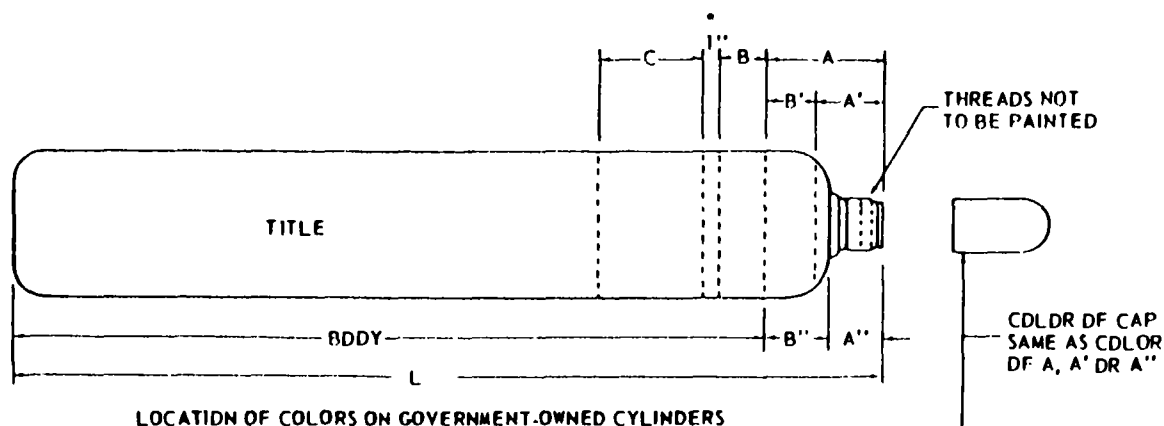
(3) Table 3-10 shows the color code which is under U. S. military standards to identify the contents of cylinders. Table 3-11 shows the color codes for certain gases in use in five foreign countries.

c. *Types of Cylinders.* Characteristics of cylinders used for certain gases are described in table 3-9.

Table 3-9. Characteristics of Gases

Gas	Color	Odor	Weight when compared to air	Physical state as shipped	Physical effect
Acetylene	None	Garliclike	Lighter	Dissolved	Anesthetic.
Ammonia	None	Pungent	Lighter	Liquid	Irritant.
Argon	None	None	Slightly heavier	Liquid	None. ¹
Carbon dioxide	None	Faint	Much heavier	Liquid	None. ¹
Chlorine	Greenish yellow	Disagreeable	Much heavier	Liquid	Irritant.
Ethylene oxide	None	Pungent	Lighter	Liquid	Irritant.
Helium	None	None	Much lighter	Gas	None. ¹
Hydrogen	None	None	Much lighter	Gas	None. ¹
Hydrogen cyanide	None	Peach blossom	Lighter	Liquid	Toxic.
Methyl chloride	None	Etherlike	Heavier	Liquid	Anesthetic.
Nitrogen	None	None	Slightly heavier	Gas	None. ¹
Oxygen	None	None	Slightly heavier	Gas	None.
Petroleum gas-Butane propane	None	Sewer gas	Heavier	Liquid	Anesthetic.
Refrigerant (Fluorocarbon)	None	None	Heavier	Liquid	None. ¹
Sulphur dioxide	None	Rotten eggs	Much heavier	Liquid	Irritant.

¹ Excessive amounts cause suffocation.



LOCATION DIMENSIONS

ON CYLINDERS FOR MEDICAL GAS MIXTURES, 1" SPACE AND BAND C ARE LOCATED IMMEDIATELY BELOW BANDS B' OR B''

CYLINDERS FOR	OVERALL LENGTH L	SHOULDER COLOR(S)			CYLINDER COLOR BAND(S)				COMMERCIAL IDENTIFICATION
		A	A'	A''	B	B'	B''	C	D
MEDICAL GAS MIXTURES	OVER 30"	L/5	3 1/2"	--	--	A LESS 3 1/2"	--	3"	L/6
OTHER GASES	"	L/5	--	--	3"	--	--	3"	L/6
MEDICAL GAS MIXTURES	30" AND UNDER	L/5	--	--	--	--	A LESS A''	2"	L/6
OTHER GASES	"	L/5	--	--	2"	--	--	2"	L/6

FROM CYLINDER TOP TO BOTTOM OF NECK RING

*1" SPACE TO BE OMITTED IF BANDS B & C ARE OF DIFFERENT COLORS

Figure 3-1. Location of colors in bottle-type cylinders.

Table 3-10. Military Standard 101A-Color Code for Compressed Gas Cylinder and Pipelines

Title	Location on cylinder			
	Top A	Band B	Band C	Body
Acetylene	Yellow	Yellow	Yellow	Yellow
Acrolein	Yellow	Brown	Black	Brown
Aerosol insecticide	Buff	Buff	Buff	Buff
Air, oil pumped	Black	Green	Green	Black
Air, water pumped	Black	Green	Black	Black
Alkyl Dicaborane	Yellow	Brown	Brown	Yellow
Alkyl Pentaborane	Yellow	Brown	Brown	Yellow
Ammonia	Brown	Yellow	Orange	Orange
Argon, oil pumped	Gray	White	White	Gray
Argon-Oxygen (% Mixture)	Gray	Green	White	Gray
Argon, water pumped	Gray	White	Gray	Gray
Boron trichloride	Gray	Brown	Gray	Brown
Boron trifluoride	Gray	Brown	Brown	Brown
Bromoacetone	Brown	Black	Black	Brown
Bromochloromethane	Buff	Gray	Buff	Buff
Bromochloromethane (Fire only)	Red	Gray	Red	Red
Bromotrifluoromethane	Orange	White	Gray	Orange
Bromotrifluoromethane (Fire only)	Red	White	Gray	Red
Butadiene	Yellow	White	Buff	Buff
Carbon dioxide	Gray	Gray	Gray	Gray
Carbon dioxide (Fire only)	Red	Red	Red	Red
Carbon monoxide	Yellow	Brown	Brown	Brown
Chloroactone	Black	Brown	Black	Brown
Chlorine	Brown	Brown	Brown	Brown
Chlorine trifluoride	Brown	Brown	Brown	Brown
Chloropicrin	Brown	Orange	Orange	Brown
Cyanogen	Yellow	Brown	Yellow	Brown
Cyclopropane, medical	Orange	Yellow	Blue	Blue
Cyclopropane, medical	Orange	Chromium plated		
Diborane	Yellow	Brown	Brown	Yellow
Dibromodifluoromethane	Buff	White	Buff	Buff
Dibromodifluoromethane (Fire only)	Red	White	Red	Red
Difluorochloroethane	Gray	Yellow	Yellow	Orange
Difluoroethane	Gray	Yellow	Orange	Orange
Dihydrotetraborane	Yellow	Brown	Brown	Yellow
Dimethylamine, anhydrous	Yellow	Blue	White	Buff
Dimethylether	Yellow	Brown	Buff	Buff
Dispersant, Dichlorodifluoromethane- Difluoroethane Mix	Buff	Gray	Gray	Buff
Ethane	Yellow	Blue	Yellow	Yellow
Ethyl chloride	Buff	Blue	Yellow	Buff
Ethyl nitrate	Yellow	Buff	Buff	Buff
Ethylamine, anhydrous	Yellow	Blue	Blue	Buff
Ethylene, industrial	Blue	Yellow	Buff	Buff
Ethylene, medical	Yellow	Blue	Blue	Blue
Ethylene oxide	Yellow	Blue	Buff	Buff
F-11, Trichlorofluoromethane	Orange	Orange	Orange	Orange
F-12, Dichlorodifluoromethane	Orange	Orange	Orange	Orange
F-13, Chlorotrifluoromethane	Orange	Orange	Orange	Orange
F-21, Dichlorofluoromethane	Orange	Orange	Orange	Orange
F-22, Chlorodifluoromethane	Orange	Orange	Orange	Orange
F-113, Trichlorotrifluoroethane	Orange	Orange	Orange	Orange
F-114, Dichlorotetrafluoroethane	Orange	Orange	Orange	Orange
F-124A, Chlorotetrafluoroethane	Orange	Orange	Orange	Orange
Fluorine	Brown	Green	Green	Brown
Fumigant, Carbon-dioxide-Ethylene oxide	Buff	Blue	Buff	Buff
Helium, oil free or medical	Buff	Gray	Gray	Gray
Helium, oil pumped	Gray	Orange	Gray	Gray
Helium-Oxygen	Buff ¹	White ²	Green	Green
Hydrogen	Yellow	Black	Yellow	Yellow

Table 3-10. Military Standard 101A-Color Code for Compressed Gas Cylinders and Pipelines—Continued

Title	Location on cylinder			
	Top A	Band B	Band C	Body
Hydrogen bromide	Black	Brown	Brown	Brown
Hydrogen chloride, anhydrous	Brown	White	Brown	Brown
Hydrogen cyanide, anhydrous	Yellow	Brown	White	Brown
Hydrogen fluoride, anhydrous	Green	Brown	Brown	Brown
Hydrogen sulfide	Brown	Yellow	Brown	Brown
Krypton, oil pumped	Gray	Buff	Buff	Gray
Krypton, water pumped	Gray	Buff	Gray	Gray
Manufactured Gas - (Specify) Coal, oil, water, producer, etc.	Brown	Yellow	Yellow	Yellow
Methane	Yellow	White	Yellow	Yellow
Methylamine	Yellow	Brown	Yellow	Buff
Methyl bromide	Brown	Black	Brown	Brown
Methyl bromide (Fire only)	Red	Brown	Red	Red
Methyl chloride	Yellow	Brown	Orange	Orange
Methyl mercaptan	Brown	Yellow	Yellow	Brown
Methyl sulfide	Yellow	Brown	Buff	Brown
Methylene chloride	Gray	Blue	Orange	Orange
Natural gas	Yellow	Brown	Yellow	Yellow
Neon, oil pumped	White	Buff	Gray	Gray
Neon, water pumped	White	Buff	Buff	Gray
Nickel carbonyl	Yellow	White	Yellow	Brown
Nitric oxide	Brown	Buff	Brown	Brown
Nitrogen dioxide	Brown	Buff	Buff	Brown
Nitrogen-Helium (% mixture)	Gray	Black	Orange	Gray
Nitrogen, oil pumped	Gray	Black	Gray	Gray
Nitrogen-Oxygen (% mixture)	Black	White	Green	Green
Nitrogen, water pumped	Gray	Black	Black	Gray
Nitrosyl chloride	Brown	White	White	Brown
Nitrous oxide	Blue	Blue	Blue	Blue
Oxygen, medical	White	Green	Green	Green
Oxygen, aviator's	Green	White	Green	Green
Oxygen	Green	Green	Green	Green
Oxygen-Carbon oxide	Gray ¹	White ²	Green	Green
Oxygen Electrolytic	Green	White	White	Green
Oxygen Fluoride	Green	Brown	Green	Brown
Ozone	Brown	Green	Green	Green
Pentaborane, Stable	Yellow	Brown	Brown	Yellow
Petroleum Gas—(Specify) Acetogen, Butane, Butane-Propane, Butane-1, Cyclopropane, Isobutane, Isobutylene, Neopentane, Propane, etc.	Yellow	Orange	Yellow	Yellow
Phenylcarbylamine chloride	Brown	Gray	Gray	Brown
Phosgene	Brown	Orange	Brown	Brown
Propylene	Yellow	Gray	Buff	Buff
Propyne	Gray	Yellow	Yellow	Yellow
Sulfur dioxide	Brown	Gray	Brown	Brown
Sulfur hexafluoride	Gray	White	Black	Gray
Tetrafluoroethylene, inhibited	Buff	White	White	Buff
Trimethylamine, anhydrous	Yellow	Blue	Orange	Buff
Vinyl bromide	Buff	Blue	Blue	Buff
Vinyl chloride	Yellow	Orange	Buff	Buff
Vinyl methly ether, inhibited	White	Black	Buff	Buff
Xenon, oil pumped	White	Black	Black	Gray
Xenon, water pumped	White	Black	Gray	Gray

¹ A' or A'' for medical gas mixtures.² B' or B'' for medical gas mixtures.

Table 3-11. Foreign Cylinder Colors

Gas	England	Australia	Japan	Italy	Germany
Acetylene	Purple	Maroon	Brown	Orange	Yellow.
Carbon dioxide	Black	Brown		Yellow	
Freon 12		Light green			
Helium	Brown	Gray			
Hydrogen	Red	Signal red	Red	Red	Red.
Methyl chloride		Light green			
Nitrogen	Gray	Dark gray	Purple	Green	Green.
Oxygen	Black	Black	Black	White	Blue.

(1) *Anhydrous ammonia.* Cylinders for anhydrous ammonia are mostly of types ICC-4, or ICC-4A 480. Type ICC-3A 480 and ICC-3A 480X are also authorized but are more expensive.

(2) *Acetylene.* Cylinders for acetylene are of type ICC-8 or ICC-8AL.

(3) *Oxygen, nitrogen, hydrogen, helium, argon air, and other nonliquefied gases.* Cylinders for these gases will be mostly of type ICC-3A 2015, ICC-3AA 2015, ICC-3A 2265, or ICC-3AA 2265. Type ICC-3A 1800 or ICC-3AA 1800 is also authorized but is less efficient. Other ICC-3A or 3AA type cylinders with service pressures higher than 2,015 and 2,265 pounds per square inch are also authorized.

(4) *Carbon dioxide, nitrous oxide and other liquefied high pressure gases.* Cylinders for these gases are mostly of type ICC-3A 1800, ICC-3AA 1800, ICC-3A 2015, or ICC-3AA 2015. ICC-3A and ICC-3AA cylinders with service pressures higher than 2,015 pounds per square inch are also authorized.

(5) *Propane, butane, and other liquefied petroleum gases.* Cylinders of types ICC-4B 240, ICC-4BA 240, ICC-4BW 240 ICC-4E 240, and ICC-4B 240X are authorized for propane, butane and other liquefied petroleum gases.

(6) *Halogenated hydrocarbons, methyl chloride, sulfur dioxide.* Cylinders for these gases will be mostly of the type ICC-4BA.

(7) *Compressed gases (except acetylene).* Cylinders of this type ICC-3E are also authorized for all compressed gases except acetylene. These will be less than 2 inches outside diameter and not over 12 inches long, exclusive of neck.

3-15. Processing and Packing

a. General. Processing and packing supplies is a highly important step connected with a shipment or storage of items so that when required they will be in usable condition. Steps in the above include proper cleaning, application of preservatives, packaging, and crating. Processing materials and their sources are dealt with in SB 38-100.

b. Cleaning. The first step in the procedure is the proper cleaning of the item. No preservative method will protect a part from corrosion if contaminating residues (deposits foreign to the composition of the part) are present on the surface.

(1) Some causes of corrosion are—

- (a) Moisture.
- (b) Perspiration from handling.
- (c) Residual soldering, welding, or brazing fluxes.
- (d) Cutting, cooling, buffing, or grinding compounds.
- (e) Dust and chemical depositis.

(2) There can be no standard choice or method of cleaning, since the cleaner selected and the method used are dependent upon the composition, nature, and construction of the part; the nature of contaminants to be removed; the degree of cleanliness required; and the availability of cleaning materials.

(a) The extent of cleaning is determined by the surface to be cleaned, varying from a highly finished part to a rough casting. Naturally, the utmost care must be taken to remove even fingerprints from highly finished surfaces.

(b) There are four approved types of cleaning materials, plus fingerprint remover or neutralizer. These are:

- 1. Petroleum solvent (Stoddard).
- 2. Alkaline cleaners.
- 3. Emulsifiable solvents.
- 4. Vapor degreasers (trichlorethylene and perchlorethylene).
- 5. Methanol (fingerprinting neutralizer).

(c) The parts must be dried after cleaning and before applying the preservative. Preferably, drying is done with compressed air or by oven-drying. Drying with a cloth is not recommended and should be used only when compressed air or oven-drying is impracticable.

c. Preservatives. The types of preservatives recommended are given in table 3-12. Further information may be obtained by reference to TM 38-230, volumes I and II. The application of preservatives may be done by dipping, spraying, brushing, flow-coating, or slushing. Dipping is the preferred method.

d. Methods of Preservation. There are six basic methods of preservation, and a number of submethods, which are used in the processing of parts and equipment. The method used depends upon the nature of the material and equipment and the degree of protection required.

(1) *Method I. Preservative coating, with greaseproof wrap when required.* Method I is used for the protection of spare parts and other equipment for shipment and storage, when the nature and construction of the items allow ready

application of a corrosive protective compound film by dipping, spraying, flushing, brushing, or fogging.

(2) *Method IA. Water-vaporproof inclosure with preservative as required.* Method IA is intended to afford adequate protection against corrosion caused by water or water vapor, and is applied to parts and equipment where critical functioning surfaces held to close tolerances are involved. Seven applications of Method IA are used.

(3) *Method IB. Strippable compound coating (hot dip).* The use of Method IB is limited to parts that have no deep recesses or complexities of structure which would prevent complete removal of the plastic coating, and whose design or contour is simple. There is also submethod IB, for the application of strippable compound.

(4) *Method IC. Waterproof barrier (with preservative as required).* Method IC consists of inclosing the item in a waterproof barrier after the required cleaning, drying, application of preservative, and cushioning, as needed. The type of waterproof barrier depends on the submethod to be used. There are six submethods.

(5) *Method II. Water-vaporproof barrier with desiccant and with preservative when required.* Method II is used for items of a highly critical nature requiring the highest degree of protection from damage by the effects of water vapor. It is applicable to mechanical or electrical items including assemblies with functional components which, by their nature, cannot be treated with a preservative. This method is *not* used on any item where the withdrawal of moisture would cause damage to the item. The use of flexible barriers is governed by the load limits outlined for the water-vaporproof barrier covered by Specification MIL-B-131. Packages weighing more than 10 pounds are fabricated only with materials qualifying as Class I under the specification. There are six submethods.

(6) *Method III. Packaging for mechanical and physical protection only.* Method III provides mechanical and physical protection only and does not afford any protection against the entry of water, water-vapor, fumes, atmospheric gases, or the growth of microorganisms. Protection against climatic and atmospheric conditions is not provided because the items packaged by Method III are, by the nature of their construction and composition, immune to such conditions.

e. Packaging and Crating.

(1) *General.* In selecting a container for

shipping, the following factors should be considered:

- (a) Suitability of articles to be packed.
- (b) Processing used for protection against corrosion.
- (c) Availability.
- (d) Cubic displacement.
- (e) Ease in handling and storing.
- (f) Type of load.

(2) *Cushioning material.* Soft material should be used as cushioning for delicate or fragile items; highly finished surfaces; small projections; protection of moisture-vaporproof and waterproof barriers, etc. However, cushioning material is not used in place of blocking material except in unavoidable cases.

(3) *Wood groups.* All woods fall into two general categories: either softwoods, which come from coniferous or needle-bearing trees; or hardwoods, which come from broad-leaved trees. For purposes of container construction, wood is divided into four *groups* based on nail holding power, tendency to split, comparative strength as a beam, and shock resisting capacity. Over 90 percent of all wooden containers are made from Group I and II woods.

(a) Group I includes the softer woods such as white fir, ponderosa pine, yellow poplar, cottonwood, cedar, and others. These woods are relatively free from splitting when being nailed, have moderate nailholding power, moderate strength as a beam, and moderate shock resisting capacity.

(b) Group II includes the harder soft woods such as Douglas fir, southern pine, hemlock, and larch. They have greater nail holding power than the Group I woods, as well as greater strength and shock resisting capacity. Group II woods are more inclined to split; the grain often deflects nails and causes them to run out at the side of the piece.

(c) Group III includes the medium density hardwoods. Ash, elm, and cherry are examples. These are similar to Group II woods in nail-holding power and strength as a beam, but have less tendency to split and shatter under impact.

(d) Group IV includes the true hardwoods such as oak, hard maple, and hickory. These woods have the greatest shock resistance and nail-holding power, are extremely strong, but are very susceptible to splitting. They are the heaviest and hardest domestic woods, and are difficult to work.

Table 3-12. Preservative Compound Chart ¹

Type	Preservative	Military	Aeronautical	Army	Navy	Application ² method and temperature	Description ³	Use ⁴
P-1	Thin film preservative (hard-drying, cold application).	Mil-C-16173C, grade 1.	-----	-----	-----	Brush, dip, or spray. 40° F-95° F.	Dries to a hard film. Thickness 0.004 in. (max). Solvent cut-back. Flash point 100° F.	On metals under outdoor conditions primarily for parts not having highly finished surfaces. Not satisfactory for parts or equipment damaged by solvent removal. NOT FOR INTRICATE ASSEMBLIES. Can frequently be used without overwrap.
P-2	Thin film preservative (soft film, cold application).	Mil-C-16173C, grade 2.	-----	-----	-----	Brush, dip, or spray. 40° F-95° F.	Non-hard-drying film. Thickness 0.002 in. (max). Solvent cut-back. Flash point 100° F.	On metals indoors where easy removability is desired. Usually requires overwrap.
P-3	Thin film preservative (soft, cold application, water displacing).	Mil-C-16173C, grade 3.	-----	-----	-----	Brush, dip, or spray. 40° F-95° F.	Non-hard-drying film. Thickness 0.001 in. (max). Solvent cut-back. Flash point 100° F. Also removable in hot water.	To displace water from previously wet surface. Usable for temporary protection.
P-6	Light preservative (hot dip, soft film).	Mil-C-11796B class 3.	-----	-----	-----	Brush, dip, or spray. Maximum temperature of application 180° F.	Thin, soft, greaselike film.	Protection of highly finished parts of complex design which can be cleaned. Especially adapted to preserving anti-friction bearings. Requires overwrap.
P-7	Medium preservative oil (cold application lubricating oil, preservative, medium).	Mil-L-3150A(1)	-----	-----	-----	Brush, dip, or spray. 60° F-120° F.	Lube oil with added inhibitors. Similar in physical properties to SAE30. Pour point 20° F.	Protection of oil-lubricated and similar operating parts. Should be supplemented by Method IA or II. DO NOT USE FOR INTERNAL COMBUSTION ENGINES. Must be removed prior to use.
P-9	Very light preservative oil (cold application).	VV-L800	-----	-----	-----	Brush, dip, or spray. 60° F-120° F.	Lube oil with added inhibitors. Flash point 275° F. Pour point	Protection of machine guns and small arms, and operating equip-

P-10	Engine preservative oil.	-----	Mil-C-6529C(2)	Mil-L-21260, Grade 1, 2, or 3.	Mil-L-21260, Grade 1, 2, or 3.	Brush, dip, or spray. 60° F-120° F.	70° F. Engine lubricating oil with corrosion inhibitors, including hydrobromic acid neutralizers. Pour point: Mil-L-21260, grade 1, 10° F. Mil-L-21260, grade 2, 0° F. Mil-C-6529, 10° F. Flash point: Mil-L-21260, grade 1, 360° F. Mil-L-21260, grade 2, 390° F. Mil-C-6529, 350° F.	ment. Need not be removed from guns prior to use. Protection of internal surface of internal combustion engines and other intricate assemblies.
P-11	Preservative grease (application as required).	-----	Mil-G-7711A	Mil-G-10924B	Mil-G-23827A	Brush. 30° F-120° F.	Lithium soap grease	Protective grease for lubricated bearings. Particularly suitable for equipment which must operate at both very low and high temperatures.
P-14	Corrosion preventive for food handling machinery and equipment (nontoxic).	Mil-C-10382B	-----	-----	-----	Spray room temperature.	Uniform mixture of white microcrystalline wax, lanolin corrosion inhibitor, 2-Amino-2-Methyl-1-Propanol, and solvent P-S-661 produces a thin film easily removed.	Food handling equipment and machinery.
P-15	Hydraulic system preservative oil. ⁵	-----	-----	-----	-----	-----	Flash point 100° F.	
P-17	Instrument bearing preservative oil.	Mil-L-6085A(2)	-----	-----	-----	Brush, dip, or spray. Room temperature.	Synthetic base lubricating oil of low volatility with additive materials to impart oxidation stability and corrosion protective properties. Pour point 70° F. Flash point 365° F.	Aircraft instruments and electronic equipment.
P-18	Volatile corrosion inhibitor.	Mil-P-3420B(1)	-----	-----	-----	Wrap of VCI-treated material.	Materials coated or impregnated with a corrosion inhibitor which	Protection of ferrous metals and approved nonmetallic compon-

See notes below table.

Table 3-12. Preservative Compound Chart¹—Continued

Type	Preservative	Military	Aeronautical	Army	Navy	Application ² method and temperature	Description ³	Use ⁴
							will volatilize and whose vapors prevent rusting of metal surfaces.	ents during shipment, handling, and storage.

Notes.

¹ *Warning.* This table is intended to correlate specification numbers with certain generally accepted types. It does not connote interchangeability, except that any compound listed under MILITARY may be used for any other with the same P number. It may, however, be used for the selection of alternative preservative compounds when the specific preservatives are not in stock or available from another source in sufficient time to accomplish the necessary preservation and when there are no specific orders to the contrary. This table is not intended to be used by contractors for the selection of alternate preservative materials unless such selection privilege is included in their contracts.

² These values are typical. Consult can label for detailed information.

³ These are typical of the most easily recognized properties.

⁴ These are the most common uses. There are many others.

⁵ Specifications for hydraulic preservative oils have not been listed because of variations in system requirements. Hydraulic preservatives used will be subject to approval by the procuring agency.

(4) *Wood quality.* The type and thickness of lumber to be used depends on the weight of the articles to be packed. Knots, cross-grain, bark, and other defects sharply reduce the strength of a board. No knot, or series of knots across the face of the board, within a length equal to the width of the board, shall have a diameter or sum of diameters greater than one-third the width of the board. No knot will exceed 4 inches when measured across the width of the board.

(5) *Nails.*

(a) When specified, the top and bottom should be nailed to the box sides.

(b) Sizes of nails are determined from the following information:

1. Nail sizes for fastening sides, top,

and bottom to ends and cleats are determined by the group of wood and the thickness of the pieces being fastened together (table 3-13).

2. Nail sizes to secure top and bottom to the sides are determined from the group of wood being used and the thickness of the side (table 3-14).

3. Nails to fasten cleats to the ends will be long enough to penetrate both the cleat and the end and be clinched at least one-eighth of an inch. However, when eight-penny nails or smaller are used, they may be clinched not more than three-eighths of an inch.

4. If the correct nail size is not available, or when splitting is encountered, one size smaller is used, and the spacing will be one-fourth of an inch closer.

Table 3-13. Size of Cooler, Sinker, and Standard Box Nails

Species of wood	Thickness of ends or cleats to which sides, tops, and bottoms are nailed											
	Exceeding	-----	7/16	½	9/16	5/8	11/16	13/16	7/8	1	1 1/8	1 1/4
	Not exceeding	7/16	½	9/16	5/8	11/16	13/16	7/8	1	1 1/8	1 1/4	-----
Group I	Size of	4	5	5	6	7	8	8	9	9	10	12
Group II	nail	4	4	5	5	6	7	7	8	9	9	12
Group III	(penny)	3	4	4	5	5	6	7	7	8	9	10
Group IV		3	3	4	4	4	5	6	7	8	8	9

Table 3-14. Size of Nails and Spacing for Nailing Tops and Bottoms to Sides of Boxes

Thickness of side (inches)	Group I wood	Group II wood	Groups III and IV wood	Spacing (inches)	
Under 3/4	No nailing permitted			<i>Minimum</i>	<i>Maximum</i>
3/4 thru 7/8, incl	7d	6d	5d	6	8
15/16 thru 1 1/16 incl	8d	7d	6d	6	8
Over 1 1/16	10d	9d	8d	8	10

(6) *Design.* Figure 3-2 shows box styles. Tables 3-15 and 3-16 show minimum thickness of box parts for various styles of box and weights of contents, for domestic shipment and easy, aver-

age, or difficult loads. Tables 3-17 and 3-18 give similar data for oversea shipments. For the case of difficult loads, and for other details, see Specification PPP-B621.

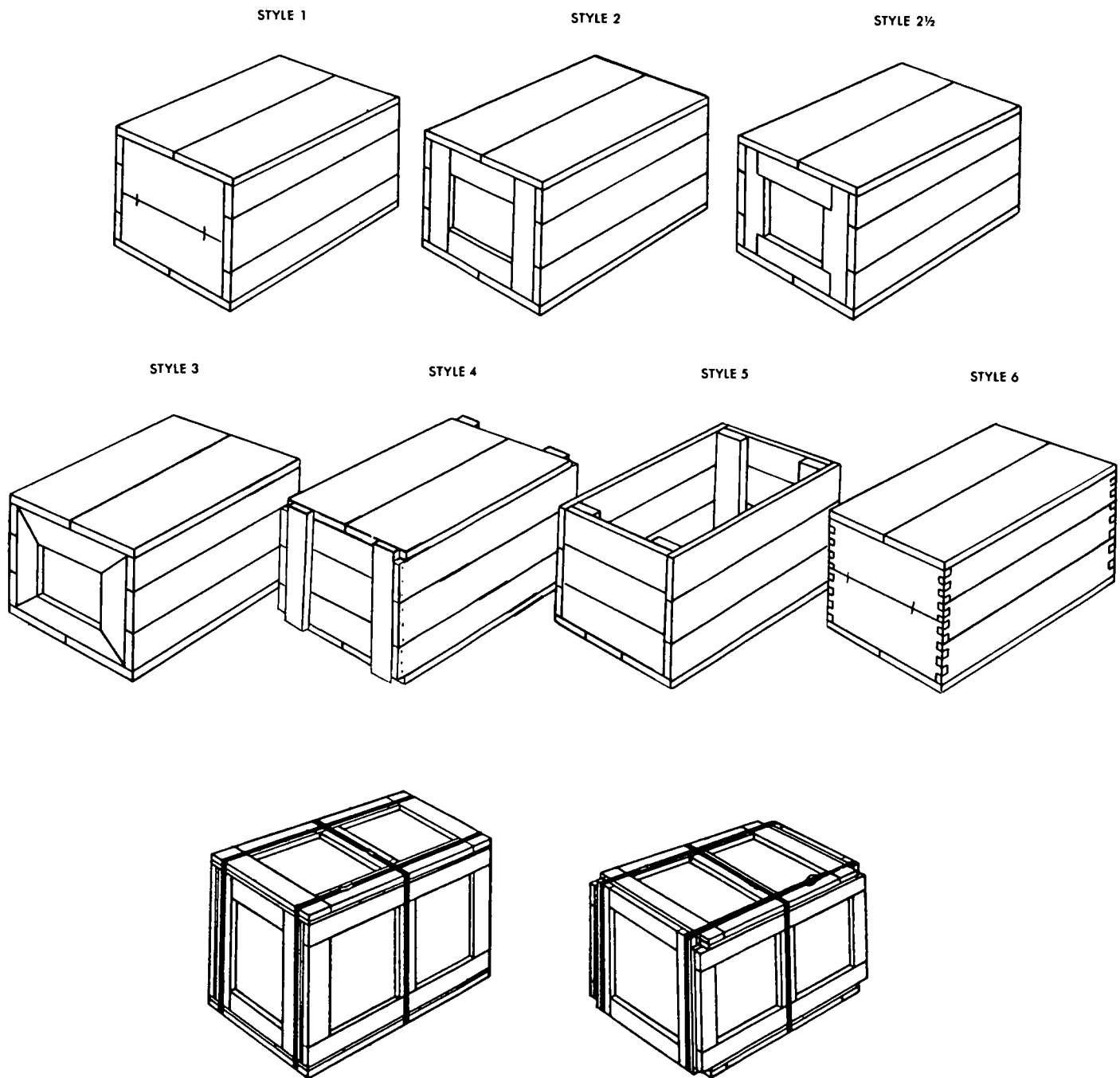


Figure 3-2. Box styles.

Table 3-15. Boxes for Domestic Shipment, Type 1 (Easy) and Type 2 (Average) Loads; Thickness of Sides, Tops, Bottoms, and Ends; and Thickness and Width of Cleats

Weight of contents		Style of box ⁵	Groups I and II woods			Groups III and IV woods		
Exceeding	Not exceeding		Thickness of sides, tops and bottoms ¹	Thickness of ends ¹	Thickness ¹ and width ² of cleats	Thickness of sides, tops and bottoms ¹	Thickness of ends ¹	Thickness ¹ and width ² of cleats
Pounds	Pounds		Inch	Inch	Inches	Inch	Inch	Inches
50	50	1	3/8	1/2		1/4	1/2	
50	50	4, 4 1/2, 5	3/8	1/2	1/2 x 1 3/4	1/4	1/2	1/2 x 1 3/4
50	50	2	3/8	3/8	3/8 x 1 1/2	1/4	3/8	3/8 x 1 1/2
50	50	6	1/4	1/2		3/16	3/8	
50	100	³ 1	3/8	3/4		3/8	3/8	
50	100	4, 4 1/2, 5	3/8	3/8	5/8 x 2 1/4	3/8	5/8	5/8 x 1 3/4
50	100	2, 2 1/2, 3	3/8	1/2	1/2 x 1 3/4	3/8	1/2	1/2 x 1 3/4
50	100	³ 6	3/8	3/4		3/8	5/8	
100	250	4, 4 1/2, 5	1/2	5/8	5/8 x 2 1/4	1/2	5/8	5/8 x 2 1/4
100	250	2, 2 1/2, 3, 7	1/2	3/8	5/8 x 1 1/2	1/2	5/8	5/8 x 1 3/4
250	⁴ 400	2, 2 1/2, 3, 7	5/8	3/4	3/4 x 2 5/8	1/2	5/8	5/8 x 2 1/4

¹ Thickness tolerance is plus or minus 1/16 inch for parts 3/8 inch thick and thicker. Thickness tolerance is plus 1/16 inch, minus 1/32 inch for pieces less than 3/8 inch thick.

² Width tolerance is plus or minus 1/16 inch.

³ Style 1 and style 6 boxes may be used to carry a net weight exceeding 50 pounds but not exceeding 100 pounds if the boxes have one-piece solid sides of sawed lumber and contents are packed in interior containers.

⁴ When load to be carried by the box exceeds 400 pounds, refer to TM 38-230-2.

⁵ Style 2, 2 1/2, 3, 4, 4 1/2 boxes. Unless otherwise specified, when the inside depth of a box is 5 inches or less, end cleats shall not be used. Thickness of the ends shall not be less than the combined thickness of the end and cleat as specified.

Each side and end shall be made from one piece except when the end is approximately square, a two-piece end with each piece of approximately equal thickness and with the grain of each piece running at right angles to the other may be used.

Two-piece end shall be nailed together with no less than 2 nails clinched.

Table 3-16. Boxes for Domestic Shipment, Type 3 (Difficult) Loads; Thickness of Sides, Tops, Bottoms, and Ends; and Thickness and Width of Cleats

Weight of contents		Style of box ⁴	Groups I and II woods			Groups III and IV woods		
Exceeding	Not exceeding		Thickness of sides, tops and bottoms ¹	Thickness of ends ¹	Thickness ¹ and width ² of cleats	Thickness of sides, tops and bottoms ¹	Thickness of ends ¹	Thickness ¹ and width ² of cleats
Pounds	Pounds		Inch	Inch	Inches	Inch	Inch	Inches
50	50	4, 4 1/2, 5	3/8	5/8	5/8 x 1 3/4	3/8	5/8	5/8 x 1 3/4
50	100	4, 4 1/2, 5	1/2	3/4	3/4 x 2 1/4	1/2	5/8	5/8 x 1 3/4
50	100	2, 2 1/2	1/2	5/8	5/8 x 1 3/4	1/2	5/8	5/8 x 1 3/4
100	250	4, 4 1/2, 5	5/8	3/4	3/4 x 2 1/4	1/2	3/4	3/4 x 2 5/8
100	250	2, 2 1/2, 3, 7	5/8	3/4	3/4 x 2 1/4	1/2	5/8	5/8 x 2 1/4
250	400	2, 2 1/2, 3, 7	3/4	3/4	1 1/16 x 3 1/4	5/8	3/4	3/4 x 2 1/4
400	³ 600	2, 2 1/2, 3, 7	3/4	13/16	1 1/16 x 3 1/4	3/4	3/4	3/4 x 2 3/4

¹ Thickness tolerance is plus or minus 1/16 inch for parts 3/8 inch thick and thicker. Thickness tolerance is plus 1/16 inch, minus 1/32 inch for pieces less than 3/8 inch thick.

² Width tolerance is plus or minus 1/16 inch.

³ When load to be carried by the box exceeds 600 pounds, refer to TM 38-230-2.

⁴ Style 2, 2 1/2, 3, 4, 4 1/2 boxes. Unless otherwise specified when the inside depth of the box is 5 inches or less, end cleats shall not be used. Thickness of the ends shall be not less than the combined thickness of the end and cleat as specified. Each side and end shall be made from one piece except when the end is approximately square, a two-piece end with each end piece approximately equal thickness and with the grain of each piece running at right angles to the other may be used. Two-piece ends shall be nailed together with no less than two nails clinched.

**Table 3-17. Boxes for Oversea Shipment, Type 1 (Easy) and Type 2 (Average)
Loads; Thickness of Sides, Tops, Bottoms, and Ends; and Thickness
and Width of Cleats**

Weight of contents		Style of box ¹	Groups I and II woods			Groups III and IV woods		
Exceeding	Not exceeding		Thickness of sides, tops and bottoms ²	Thickness of ends ²	Thickness ² and width ³ of cleats	Thickness of sides, tops and bottoms ²	Thickness of ends ²	Thickness ² and width ³ of cleats
Pounds	Pounds		Inch	Inch	Inches	Inch	Inch	Inches
-----	50 -----	4, 4 1/2, 5 -----	3/8	5/8	5/8 x 1 3/4	3/8	5/8	5/8 x 1 3/4
50 -----	100 -----	4, 4 1/2, 5, 7 -----	1/2	3/4	3/4 x 2 1/4	3/8	5/8	5/8 x 1 3/4
100 -----	250 -----	4, 4 1/2, 5 -----	5/8	3/4	3/4 x 2 1/4	1/2	3/4	3/4 x 2 1/4
100 -----	250 -----	2, 2 1/2, 3, 7 -----	5/8	5/8	5/8 x 2 1/4	1/2	5/8	5/8 x 2 1/4
250 -----	400 -----	4, 4 1/2, 5 -----	3/4	3/4	3/4 x 2 5/8	5/8	3/4	3/4 x 2 1/4
250 -----	400 -----	2, 2 1/2, 3, 7 -----	3/4	13/16	3/5 x 2 5/8	5/8	3/4	3/4 x 2 1/4
400 -----	600 -----	2, 2 1/2, 3, 7 -----	13/16	13/16	13/16 x 2 5/8	5/8	3/4	3/4 x 2 1/4
600 -----	1000 -----	(see table 3-18)						

¹ For style 2, 2 1/2, 3, 4, 4 1/2 boxes, unless otherwise specified, when the inside depth of a box is 5 inches or less, end cleat shall not be used. Thickness of the ends shall not be less than the combined thickness of the end cleat as specified. Each side and end shall be made from one piece except when the end is approximately square, a two-piece end with each end approximately equal thickness and with the grain of each piece running at right angles to the other may be used. Two-piece ends shall be nailed together with no less than two nails clinched.

² Thickness tolerance is plus or minus 1/16 inch for parts 3/8 inch thick and thicker. Thickness tolerance is plus 1/16 inch, minus 1/32 inch for pieces less than 3/8 inch thick.

³ Width tolerance is plus or minus 1/16 inch.

**Table 3-18. Boxes for Overseas Shipment, Type 3 (Difficult) Loads; Minimum
Thickness of Sides, Tops, Bottoms, and Ends; and Thickness and Width of Cleats**

Weight of contents		Style of box ¹	Groups I and II woods			Groups III and IV woods		
Exceeding	Not exceeding		Thickness of sides, tops and bottoms ²	Thickness of ends ²	Thickness ² and width ³ of cleats	Thickness of sides, tops and bottoms ²	Thickness of ends ²	Thickness ² and width ³ of cleats
Pounds	Pounds		Inch	Inch	Inches	Inch	Inch	Inches
-----	100 -----	4, 4 1/2, 5 -----	1/2	3/4	3/4 x 2 1/4	1/2	5/8	5/8 x 1 3/4
-----	100 -----	2, 2 1/2, 3, 7 -----	1/2	5/8	5/8 x 2 1/4	1/2	5/8	5/8 x 1 3/4
100 -----	250 -----	4, 4 1/2, 5 -----	5/8	3/4	3/4 x 2 5/8	1/2	3/4	3/4 x 2 1/4
100 -----	250 -----	2, 2 1/2, 3, 7 -----	5/8	3/4	3/4 x 2 1/4	1/2	5/8	5/8 x 2 1/4
250 -----	400 -----	4, 4 1/2, 5 -----	3/4	1 1/16	1 1/16 x 3 1/4	5/8	13/16	13/16 x 2 3/4
250 -----	400 -----	2, 2 1/2, 3, 7 -----	3/4	3/4	1 1/16 x 3 1/4	5/8	3/4	3/4 x 2 3/4
400 -----	600 -----	2, 2 1/2, 3, 7 -----	13/16	13/16	1 1/16 x 3 1/4	3/4	13/16	13/16 x 2 3/4
600 -----	800 -----	2, 2 1/2, 3, 7 -----	13/16	1 1/16	1 1/16 x 3 1/4	3/4	13/16	13/16 x 2 3/4
800 -----	1000 -----	2, 2 1/2, 3, 7 -----	1 1/16	1 5/16	1 5/16 x 4 1/8	7/8	1 1/16	1 1/16 x 3 3/8

¹ Style 2, 2 1/2, 3, 4, 4 1/2 boxes. Unless otherwise specified, when the inside depth of a box is 5 inches or less, end cleats shall not be used. Thickness of the ends shall be not less than the combined thickness of the end and cleat as specified. Each side and end shall be made from one piece except when the end is approximately square, a two-piece end with each piece of approximately equal thickness and with the grain of each piece running at right angles to the other may be used. Two-piece ends shall be nailed together with no less than two nails clinched.

² Thickness tolerance is plus or minus 1/16 inch for parts 3/8 inch and thicker. Thickness tolerance is plus 1/16 inch, minus 1/32 inch for pieces less than 3/8 inch thick.

³ Width tolerance is plus or minus 1/16 inch.

CHAPTER 4

SOILS

4-1. Scope

For a detailed treatment of control of soils in military construction, refer to TM 5-330. This chapter will present only the essential charts and tables for ready reference, with a minimum of explanation.

4-2. Soil Classification

Table 4-1 gives the definition of soil groups on the basis of grain size in accordance with the Unified Soil Classification System. Table 4-2 summarizes the Unified Soil Classification System, giving names, letter symbols, definitions, and general information about soils.

Table 4-1. Definition of Soil Groups on the Basis of Grain Size (USCS)

	U.S. standard sieve size	
	Passing	Retained on
Cobbles	No maximum size	3-inch
Gravel	3-inch	No. 4
Sand	No. 4	No. 200
Fines	No. 200	(^a)
Organic material	(^b)	(^b)

^a No minimum size.

^b No size boundary.

4-3. Identification of Soils

Figure 4-1 gives a summary of a soil identification procedure, using laboratory test results. Figures 4-2 outlines a procedure for soil identification in the field.

4-4. Pertinent Characteristics of Soils

Table 4-3 summarizes the characteristics of soils which are pertinent to road and airfield construction.

4-5. Soil Stabilization

For roads and airfields in the theater of operations, there are three primary functions which may be served by soil stabilization:

a. Strength improvement; to improve the stability of the existing soil to enhance its load-carrying capability.

b. Dust control; to eliminate or alleviate the generation of dust by vehicle and aircraft operations.

c. Soil waterproofing; to preserve the natural or constructed strength of a soil by preventing the ingress of surface water. Tables 4-4 through 4-7 provide guidance for determining the requirements for soil stabilization under various conditions, and the materials and methods for accomplishing the required stability.

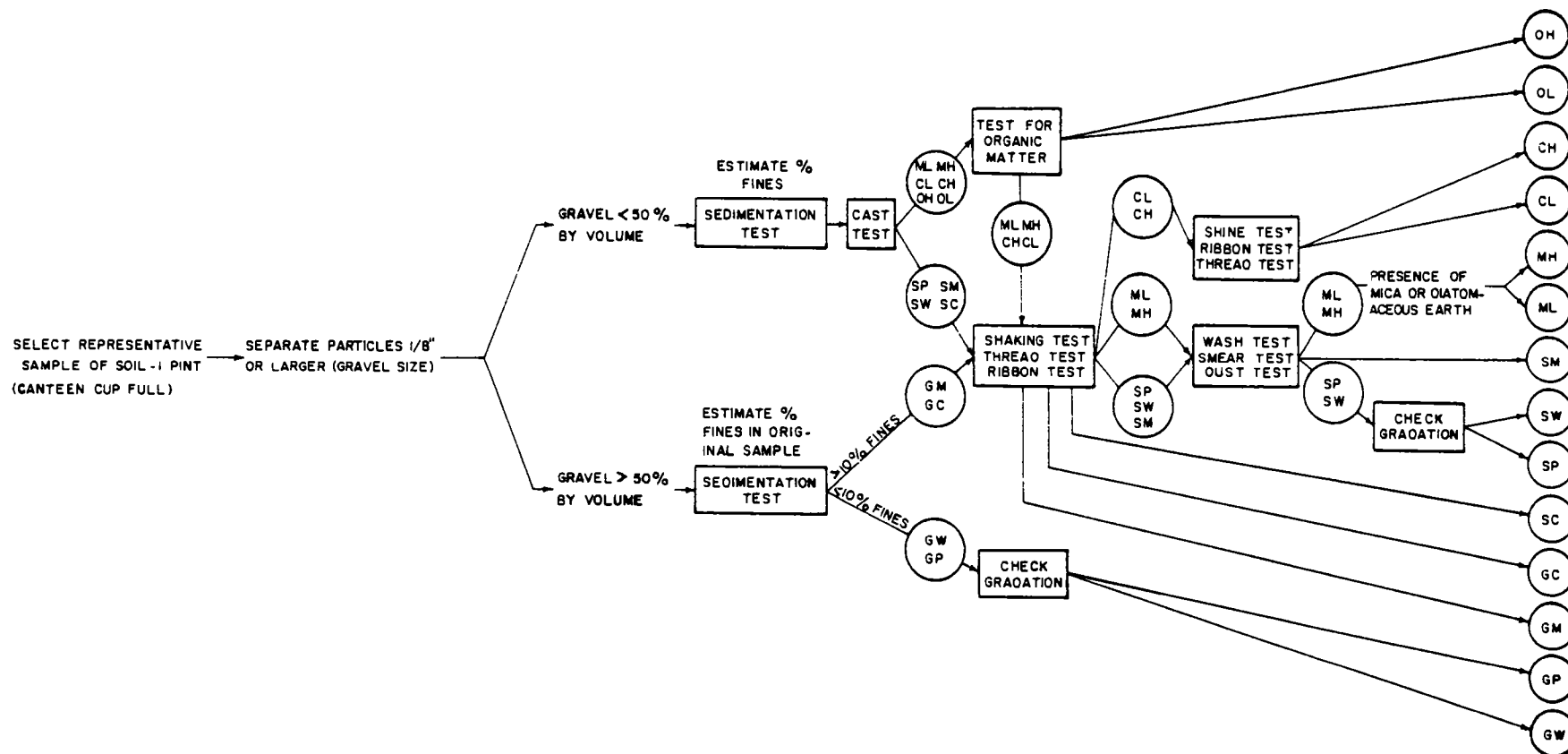


Figure 4-2. Suggested procedure for field identification.

*Figure 4-1. Identification of soils under Unified
Soils Classification System.*

(Located in back of manual.)



Table 4-2. Unified Soil Classification System

(Located in back of manual.)



Table 4-6. Summary of Soil Stabilizers for Strength Improvement Function

(1) Material	(2) Form of material	(3) Applicable soil range	(4) Estimated range of quantity requirements (%) [†]	(5) Minimum curing time requirements
Portland cement	Powder	Gravels Sands Silt, clayey silts Clays	3-4 3-5 4-6 6-8	24 hours
Lime				
1. Hydrated	Powder	Clayey gravels Silty clays Clays	2-4 5-10 3-8	7 days
2. Quicklime	Powder	Clayey gravels Silty clays Clays	2-3 3-8 3-6	4 hours
Bituminous material				
1. Asphaltic cutbacks				
a. RC-70 to RC-800	Liquid	Sands Silty sands Clayey sands	5-7 ^{††} 6-10 6-10	1-3 days
b. MC-70 to MC-800	Liquid	Sands Silty sands Clayey sands	5-7 6-10 6-10	1-3 days
2. Asphaltic emulsions	Liquid	Sands Silty sands Clayey sands	5-7 6-10 6-10	1-3 days

[†] Based on dry density of existing soil.

^{††} All quantities listed for asphalts are actual bitumen requirements, exclusive of volatiles.

Table 4-7. Summary of Soil Stabilizing Materials for Function of Dust Control and/or Soil Waterproofing

Primary function, Area of application, and degree of effectiveness †										
(1) Material	(2) Form of material	(3) Acceptable application method (s)	(4) Applicable soil range	Dust palliative		(7) Waterproof (traffic or limited traffic areas only)	Quantity requirements ††		(10) Minimum curing time requirements	(11) Remarks
				(5) Traffic	(6) Nontraffic or limited traffic		(8) gal per sq yd	(9) lb per sq yd		
Group I: Bituminous materials										
Cutback Asphalts										
a. RC-70 to RC-250	Liquid	Admix Penetration	Gravel to sand	M	V	M	0.18-0.25	1.5-2.0	12-24 hr	All cutback asphalts will require preheating for penetration or admix application.
			Gravel to silty sand.	M	V	X	0.25-0.50	2.1-4.0	12-24 hr	
b. MC-70 to MC-250	Liquid	Admix	Sand to silt	M	V	M	0.25-0.55	2.0-4.5	24 hr	
c. MC-30 to MC-250	Liquid	Penetration	Gravel to silty sand.	M	V	X	0.25-0.50	2.1-4.0	24 hr	
d. SC-70 to SC-250	Liquid	Admix	Sand to clay of moderate plasticity.	M	V	M	0.55-0.72	4.5-6.0	24 hr	
		Penetration	Gravel to silty sand.	M	V	X	0.25-0.50	2.1-4.0	24 hr	
Road Tars										
a. RT-3 to RT-6	Liquid	Admix	Gravel to clay of moderate plasticity.	V	V	V	0.30-0.50	2.5-4.0	Several days	Same comments as above for cutbacks.
b. RT-1 to RT-6	Liquid	Penetration	Gravel to silty sand.	X	X	X	0.25-0.50	2.1-4.0	Several days	
Emulsified Asphalts										
a. SS-1 or SS-1h (Anionic)	Liquid	Admix	Gravel to silty sand.	X	X	X	0.10-0.50 (diluted)	0.8-4.0	Several hr	Requires water for dilution and requires careful control for proper emulsion break. Dilutions up to 5:1 by water are used.
		Penetration	Gravel to silty sand.	X	X	X	0.10-0.50	0.8-4.0	Several hr	
Special Asphalts										
a. Penepime *	Liquid	Penetration	Gravel to clay of moderate plasticity.	M	V	M	0.25-0.5	2.1-4.0	4-8 hr	Excellent penetration ability; requires heating for spraying.
Group II: Cementing Material										
Portland Cement	Powder	Admix	All	S	S	S	--	1.5-4.0	12-24 hr	Normally used for strength, but will also provide modest benefits

Table 4-8. Characteristics Pertinent to Roads and Airfields

(Located in back of manual.)



Table 4-4. Stabilization Functions Pertinent to Theater of Operations Airfields

Airfield type	Possible functions of stabilization for indicated areas					
	Traffic areas †			Nontraffic areas ††		
	Strength improvement	Dust control	Soil waterproofing	Strength improvement	Dust control	Soil waterproofing
Battle area:						
Light lift		X	X		X	
Medium lift:						
a. No mat	X	X	X		X	
b. With LM					X	
Forward area:						
Liaison		X	X		X	
Surveillance:						
a. No mat	X	X	X		X	
b. With LM					X	
Light lift		X	X		X	
Medium lift:						
a. No mat	X	X	X		X	
b. With LM					X	
Support area:						
Liaison		X	X		X	
Surveillance:						
a. No mat		X	X		X	X
b. With LM					X	X
Light lift		X	X		X	
Medium lift:						
a. No mat	X	X	X	X	X	X
b. With LM	X			(X)	(X)	(X)
c. With MM				(X)	(X)	(X)
Heavy lift:						
a. No mat	X	X	X	X	X	X
b. With LM	X			(X)	(X)	(X)
c. With MM	X			(X)	(X)	(X)
Tactical:						
a. No mat				X	X	X
b. With LM	X			(X)	(X)	(X)
c. With MM				(X)	(X)	(X)
Rear area:						
Army:						
a. No mat	X	X	X		X	X
b. With LM					X	X
Medium lift:						
a. No mat	X	X	X	X	X	X
b. With LM	X			(X)	(X)	(X)
c. With MM	X			(X)	(X)	(X)
Heavy lift:						
a. No mat				X	X	X
b. With LM	X			(X)	(X)	(X)
c. With MM	X			(X)	(X)	(X)
Tactical:						
a. No mat				X	X	X
b. With LM	X			(X)	(X)	(X)
c. With MM	X			(X)	(X)	(X)

Note. 1. Reference to the use or no use of mat for a particular airfield apply only to their use in traffic areas.

2. X = functions for which stabilization may be considered, blank space = no function for stabilization, (X) = function will exist only if landing mat is not used in nontraffic areas.

† Traffic areas include runway, taxiways, and aprons.

†† Nontraffic areas include overruns, shoulders, and peripheral zones which receive little or no traffic.

Table 4-5. Design Requirements for Strength Improvement Function of Soil Stabilization

Pertinent airfield type	Traffic areas							Nontraffic areas						
	Minimum stabilization strength required †	Thickness of soil stabilization required (in.) for subgrade airfield index of						Minimum stabilization strength required †	Thickness of soil stabilization required (in.) for subgrade airfield index of					
		5-6	6-8	8-10	10-12	12-15	>15		5-6	6-8	8-10	10-12	12-15	>15
Battle area:														
Medium lift:														
a. No mat	6	11												
Forward area:														
Surveillance:														
a. No mat	8	8	7											
Medium lift:														
a. No mat	8	15	12											
Support area:														
Medium lift:														
a. No mat	10	22	18	12				6	10					
b. With LM	8	10	6											
Heavy lift:														
a. No mat	15	40	29	19	14	10		9	10	9	7			
b. With LM	10	28	18	8										
c. With MM	6	18												
Tactical:														
a. No mat								11	7	6	5	5		
b. With LM	10	8	6	5										
Rear area:														
Army:														
a. No mat	10	12	10	8										
Medium lift:														
a. No mat	15	30	26	18	14	10		8	12	10				
b. With LM	10	18	14	6										
c. With MM	6	8												
Heavy lift:														
a. No mat								12	14	12	10	9		
b. With LM	12	42	33	16	5			6	5					
c. With MM	8	33	22											
Tactical:														
a. No mat								13	10	8	6	5		
b. With LM	12	12	9	5	5									
c. With MM	8	7	5											

Note. Practical limitations generally will preclude the consideration of chemical stabilization methods to develop an improved quality layer in excess of 16 inches thick.

† Airfield index, index of soil strength determined by Cone Penetrometer.

Lime (Hydrated)	Powder	Admix	Clays of moderate to high plasticity.	S	S	S	--	1.5-4.0	12-24 hr	for dust control and waterproofing when used in low quantities as a soil modifier. Same as cement above.
Group III: Resinous Systems										
Lignin	Liquid or Powder.	Admix	Sand to clay of low plasticity.	S	S	S	--	4.0-8.0	12-24 hr	Benefits may be only temporary since resin is water soluble.
		Penetration	Sand to silty sand.	X	X	X	0.50-1.0	4.0-8.0	2-6 hr	
Concrete Curing Compound (with paraffin base resin).	Liquid	Penetration	Silts to clays	S	M	X	0.1-0.2	1.0-2.0	2 hr	Fairly viscous; requires special spray nozzles, forms thick moderately flexible film on surface when cured; curing depends on temperature and humidity.
Group IV: Salts										
Sodium Chloride	Granules	Admix	Gravel to silt (with fines present).	S	S	--	--	0.4-0.8	0	All salts are corrosive to metal; subject to leaching; rely on absorption of moisture from air to palliate dust. Brine solution forms surface crust.
Calcium Chloride	Powder Admix or flake.	Admix	Gravel to silt (with fines present).	S	S	--	--	0.4-0.8	0	
Brine Solution	Liquid	Penetration	Sand to clay of low plasticity.	S	S	--	0.5-1.5 (20% solution)			
Group V: Miscellaneous Materials										
Water	Liquid	Penetration	All	S	S	--	(As needed)		0	Temporary measure only. Temporary measure only; may require frequent application.
Various Oils	Liquid	Penetration	All	S	X	--	0.5-1.0		0	

† Relative degree of effectiveness is indicated as follows: S = slightly, M = moderately, V = very, X = Applicable, but effectiveness unknown, Blank = not applicable.

†† For all admixture treatments, the quantities indicated are for a 1-in. depth of treatment and assume a compacted dry density of 100 lb. per cu. ft.

* Proprietary material.

4-6. Soils Trafficability

Soils trafficability deals with the capacity of soils to support cross-country movement of vehicles. Soil-trafficability measurements, obtained by use of the soil trafficability test set, are resolved into the "rating cone index". The "vehicle cone index" is determined by formula, incorporating all characteristics of the vehicle which affect its cross-country capabilities. Detailed procedures for obtaining vehicle cone index and soil rating cone index are covered in TM 5-330. Matching "vehicle cone index" with the soil "rating cone index" provides a scientific method for determining suitability of cross-country routes. To simplify this procedure, military vehicles have been grouped into seven categories as indicated in table 4-8. Table 4-9 gives the vehicle cone index and category for current military vehicles.

Table 4-8. Categories of Vehicles

Category	Cone index range	Vehicles
1	20-29	The M29 weasel, M76 Otter, and Canadian snowmobile are the only known standard vehicles in this category.
2	30-49	Engineer and high-speed tractors with comparatively wide tracks and low contact pressures.
3	50-59	The tractors with average contact pressures, the tanks with comparatively low contact pressures, and some trailed vehicles with very low contact pressures.
4	60-69	Most medium tanks, tractors with high contact pressures, and all wheel-drive trucks and trailed vehicles with low contact pressures.
5	70-79	Most all wheel-drive trucks, a great number of trailed vehicles, and heavy tanks.
6	80-99	A great number of all wheel-drive and rear-wheel-drive trucks, and trailed vehicles intended primarily for highway use.
7	100 or greater	Rear-wheel-drive vehicles and others that generally are not expected to operate off roads, especially in wet soils.

Table 4-9. Cone Index Requirements Tracked Vehicles

Vehicle description	Vehicle weight (in kips)	Vehicle cone index	Category
Amphibious Vehicles			
Assault vehicle, full tracked, amphibious: XM733 FSN 2320-999-4312.	10.5	30	2
Carrier, cargo, amphibious, tracked: M76	12.2	22	1
Carrier, cargo, amphibious, tracked: M116 (T116E1)	10.9	29	1
Landing vehicle, tracked, MK4	36.4	54	3
Landing vehicle, tracked, armored MK4	40.0	58	3
Landing vehicle, tracked, engineer M1 (LVTE1)	97.5	58	3
Landing vehicle, tracked, command M5 (LVTP5A1 (CMD))	97.5	58	3
Landing vehicle, tracked, personnel M5 (LVTP5A1)	87.8	55	3
Landing vehicle, tracked, howitzer M6 (LVTH6A1)	86.6	54	3
Landing vehicle, tracked, recovery M1 (LVTR1A1)	82.2	53	3
Tank, combat, full tracked: counterinsurgency, amphibious, lt wt, XM729 FSN 2350-921-5564.	10.5	30	2
Armored Bulldozers			
Bulldozer, earthmoving M6, tank mtd (tank, combat, 90mm gun M47)	107.8	66	3
Bulldozer, earthmoving M8 (tank, combat, 90mm gun M48)	107.8	54	3
Bulldozer, earthmoving tank mtd, M9 (tank, combat, 105mm gun, M60 and M60A1).	116.0	52	3
Combat Vehicles			
Armored reconnaissance airborne assault vehicle (General Sheridan) M551.	33.6	42	2
Flamethrower, self-propelled:			
M132	23.3	49	2
M132A1	23.9	49	2

Table 4-9. Cone Index Requirements

Vehicle description	Vehicle weight (in kips)	Vehicle cone index	Category
<i>Tracked Vehicles—Continued</i>			
Gun, antiaircraft artillery, self-propelled: twin 40 mm:			
M19A1	41.2	57	3
M42	49.5	45	2
M42A1	49.5	45	2
Gun, field artillery, self-propelled, 155mm, M53, (T97)	96.0	56	3
Gun, antitank, self-propelled: 90mm, M56	15.5	34	2
Gun, field artillery, self-propelled: 175mm, M107 (T235E1)	62.1	59	3
Howitzer, heavy, self-propelled, full tracked: 8 inch M55 (T108)	98.0	56	3
Howitzer, heavy, self-propelled: 8 inch M110 (T236E1)	58.5	56	3
Howitzer, light, self-propelled, full tracked: 105mm, M37	46.0	58	3
Howitzer, light, self-propelled, full tracked: 105mm:			
M52	53.0	46	2
M52A1	53.0	46	2
Howitzer, light, self-propelled: 105mm, M108 (T195E1)	46.9	54	3
Howitzer, medium, self-propelled, full tracked: 155mm:			
M44	64.0	42	2
M44A1	64.0	42	2
Howitzer, medium, self-propelled: 155mm, M109 (T196E1)	52.5	63	4
Mortar, infantry, self-propelled, full-tracked: 107mm, (4.2 inch) M84	47.1	46	2
Rifle, self-propelled, full tracked: multiple; 106mm, M50	19.0	37	2
Tank, combat, full tracked: 76mm gun:			
M41	51.8	49	2
M41A1	51.8	49	2
M41A2	51.8	49	2
M41A3	51.8	49	2
Tank, combat, full tracked: 90mm gun:			
M47	101.8	64	4
M48	99.0	50	3
M48C	99.0	50	3
M48A1	104.0	58	3
M48A2	105.0	58	3
M48A2C	105.0	58	3
M48A3 (M48A1E2)	104.0	58	3
Tank, combat, full tracked: 105mm gun:			
M60	102.0	49	2
M60A1	102.0	49	2
Tank, combat, full tracked: 120mm gun:			
M103	125.0	61	4
M103A1	125.0	61	4
Tank, combat, full tracked: flamethrower, M67A1	105.8	58	3
Tractor, full tracked, high speed: 13 ton:			
M5	28.6	72	5
M5A1	30.4	77	5
M5A2	26.1	39	2
M5A4	29.8	46	2
M5A3	30.4	41	2
Tractor, full tracked, high speed: 32 ton:			
M8A1	55.0	42	2
M8A2	55.0	42	2
Vehicle, combat engineer, full tracked: 165mm gun, M728 (T118E1) (basic M60A1 tank) FSN 2350-795-1797.	115.0	59	3
<i>Armored Vehicle Launched Bridges</i>			
Launcher, M48 tank chassis, transporting	96.0	49	2
Launcher, M48 tank chassis, transporting, with bridge, armored vehicle launched, scissoring type, class 60: 60-foot.	128.0	65	4
Launcher, M60A1 chassis, transporting	86.3	45	2
Launcher, M60A1 chassis, transporting, with bridge, armored vehicle launched, scissoring type, class 60: 60-foot.	115.9	60	4

Table 4-9. Cone Index Requirements

Vehicle description	Vehicle weight (in kips)	Vehicle cone index	Category
<i>Tracked Vehicles—Continued</i>			
<i>Carriers</i>			
Carrier, cargo, tracked: 6 ton, M548	28.0	37	2
Carrier, command post, light, tracked:			
M577	23.9	49	2
M577A1	24.4	49	2
Carrier, command and reconnaissance, armored:			
M114A1	14.7	38	2
M114	14.7	38	2
Carrier, guided missile equipment, full tracked: XM474E2 w/e (PERSHING), FSN 1450-831-6942.	11.9	44	2
Carrier, 107mm (4.2 in) Mortar, self-propelled:			
M84	47.1	46	2
Carrier, personnel, full tracked: armored, M59	42.6	44	2
Carrier, personnel, full tracked: armored, M75	41.5	44	2
Carrier, personnel, full tracked: armored:			
M113 (T113E2)	22.6	48	2
M113A1	23.4	49	2
<i>Recovery Vehicles</i>			
Recovery vehicle, full tracked: heavy, M51	120.0	59	3
Recovery vehicle, full tracked: medium, M88	112.0	56	3
Recovery vehicle, full tracked: light, armored, M578 (T120E1)	54.0	58	3
<i>Wheeled Vehicles</i>			
<i>Amphibious Vehicles</i>			
Bridge, float, mobile assault, amphibious, (French)	59.4	267	7
Lighter, amphibious, self-propelled, cargo: 5 ton, LARC-V, design 8005	31.0	68	4
Lighter, amphibious, self-propelled, cargo: 15 ton, LARC-XV, design 8004.	75.0	170	7
Transporter, amphibious, self-propelled, with superstructure, end bay mobile assault bridge (MAB).	60.4	291	7
Transporter, amphibious, self-propelled, with superstructure, interior bay mobile assault bridge (MAB).	59.4	280	7
<i>Missile Vehicles</i>			
Launcher, Rocket: 762mm, truck mounted, (Honest John System):			
(M139 chassis), M386, w/e	40.2	65	4
(M139D chassis), M289, w/e	47.7	82	6
Loader-transporter, guided missile, XM501E2 w/e (HAWK) FSN 1450-768-7046.	8.5	102	7
Loader-transporter, guided missile, XM501E3 w/e (HAWK) FSN 1450-066-8873.	9.5	75	7
<i>Transporters</i>			
Transporter, CONEX, 6 x 6, 16 ton	76.0	160	7
<i>Trucks</i>			
Truck, cargo: $\frac{3}{4}$ ton, 4 x 4:			
M37	7.4	61	4
M37B1	7.4	61	4
Truck, cargo: 1 $\frac{1}{4}$ ton, 6 x 6, M561	9.6	44	2
Truck, cargo: 2 $\frac{1}{2}$ ton, 6 x 6, M34	17.2	61	4
Truck, cargo: 2 $\frac{1}{2}$ ton, 6 x 6, M35A1	19.2	59	3
Truck, cargo: 2 $\frac{1}{2}$ ton, 6 x 6:			
M36	18.9	61	4
M36C	18.9	61	4
Truck, cargo: 2 $\frac{1}{2}$ ton, 6 x 6, M135	18.7	61	4
Truck, cargo: 2 $\frac{1}{2}$ ton, 6 x 6, M211	18.6	59	3
Truck, cargo: 5 ton, 6 x 6, M41	29.8	67	4
Truck, cargo: 5 ton, 6 x 6, M54	30.6	67	4
Truck, cargo: 5 ton, 8 x 8, M656	25.6	42	2
Truck, cargo: 8 ton, 4 x 4, M520 (GOER)	43.4	97	6
Truck, cargo: 10 ton, 6 x 6:			
M125	49.5	84	6
M125A1	49.5	84	6

Table 4-9. Cone Index Requirements

Vehicle description	Vehicle weight (in kips)	Vehicle cone index	Category
<i>Wheeled Vehicles—Continued</i>			
Truck, dump: 2½ ton, 6 x 6, M47	19.2	64	4
Truck, dump: 2½ ton, 6 x 6, M59	19.5	58	3
Truck, dump: 2½ ton, 6 x 6, M215	18.6	59	3
Truck, dump: 2½ ton, 6 x 6, M342A2	20.6	76	5
Truck, dump: 5 ton, 6 x 6; M51	32.7	72	5
M51A2	32.7	72	5
Truck, maintenance: ¾ ton, 4 x 4, M201B1	8.8	66	4
Truck, maintenance, earthboring: 2½ ton, 6 x 6, V18A/MTQ	19.5	67	4
Truck, maintenance, telephone construction and maintenance: 2½ ton, 6 x 6, V17A/MTQ	18.8	65	4
Truck, platform, utility: ½ ton, 4 x 4, M274	2.1	32	2
M274A1	2.1	32	2
M274A2	2.1	32	2
M274A3	2.1	32	2
M274A4	2.1	32	2
Truck, tank, fuel servicing: 2½ ton, 6 x 6, 1200 gal. M217 (w/600 gal)	19.6	62	4
M217C (w/600 gal)	19.6	62	4
Truck, tank, fuel servicing: 2500 gal, 4 x 4, M559 (GOER): (w/2500 gal)	43.2	111	7
(empty)	27.6	55	3
Truck, tank, gasoline: 2½ ton, 6 x 6, 1200 gal, M49 (w/600 gal)	18.8	60	4
M49C (w/600 gal)	18.8	60	4
Truck, tank, water: 2½ ton, 6 x 6, 1000 gal: M50	18.9	61	4
M222	18.0	57	3
Truck, tractor: 2½ ton, 6 x 6; M48 (w/o payload)	18.8	46	2
M221 (w/o payload)	19.5	46	2
M275 (w/o payload)	18.6	46	2
Truck, tractor: 5 ton, 6 x 6; M52 (w/o payload)	34.5	52	3
M52A1 (w/o payload)	34.5	52	3
Truck, tractor: 10 ton, 6 x 6; M123 (w/o payload)	62.2	52	3
M123C (w/o payload)	62.2	52	3
M123D (w/o payload)	62.2	52	3
Truck, tractor: 12 ton, 6 x 6, M26A1 (w/o payload)	48.9	79	5
Truck, tractor, wrecker: medium, 5 ton, 6 x 6, M246 (w/payload)	44.8	73	5
Truck, utility: ¼ ton, 4 x 4: M38	3.6	48	2
M38A1	3.5	47	2
M38A1C	3.5	47	2
Truck, utility: ¼ ton, 4 x 4, M151	3.1	41	2
Truck, utility: ¼ ton, 4 x 4, lightweight, M422A1	2.6	41	2
Truck, van, expandable: 2½ ton, 6 x 6, M292	25.1	76	5
Truck, van, shop: 2½ ton, 6 x 6, M109A1	21.0	65	4
Truck, van, shop: 2½ ton, 6 x 6, M220	20.4	62	4
Truck, wrecker, crane: 2½ ton, 6 x 6, M108	19.8	63	4
Truck, wrecker, light: 2½ ton, 6 x 6, M60	24.5	74	5
Truck, wrecker, medium: 5 ton, 6 x 6, M62	41.0	74	5
Truck, wrecker, medium: 5 ton, 6 x 6, M543	34.4	76	5
Truck wrecker: 10 ton, 4 x 4, XM553 (GOER), (w/o payload) FSN 2320-873-5426.	40.2	94	6

Table 4-9. Cone Index Requirements

Vehicle description	Vehicle weight (in kips)	Vehicle cone index	Category
<i>Construction Equipment</i>			
<i>Earthmoving Tractors</i>			
Tractor, full tracked, low speed: DED, heavy dbp, w/bulldozer, w/scarifier			
IH Model TD-24-241 FSN 2410-542-2338	54.2	52	3
Caterpillar Model D-8 FSN 2410-542-4882	51.0	50	3
Tractor, full tracked, low speed: DED, medium dbp, w/bulldozer, cable PCU Caterpillar Model D-7 FSN 2410-277-1280.	35.8	47	2
Tractor, full tracked, low speed: DED, medium dbp, w/angledozer, w/scarifier, IH Model TD-18-182 FSN 2410-541-7655.	39.8	44	2
Tractor, full tracked, low speed: DED, medium dbp, w/angledozer, w/scarifier, IH Model TD20-200 FSN 2410-542-2498.	40.2	45	2
Tractor, full tracked, low speed: DED, light dbp, w/bulldozer, w/scarifier, Caterpillar Model D-6 FSN 2410-542-4206.	16.0	50	3
Tractor, full tracked, low speed: DED, light dbp, w/bulldozer, w/scarifier, w/wn, Caterpillar Model D-4 FSN 2410-843-6374.	17.3	58	3
Tractor, full tracked, low speed: DED, light dbp, w/bulldozer, PCU Hydraulic crane; Caterpillar Model 933 FSN 2410-555-1756.	16.0	57	3
Tractor, full tracked, low speed: DED, medium dbp, w/bulldozer, w/scarifier:			
Allis Chalmers HD-16M FSN 2410-078-6483	48.5	47	2
Caterpillar Model D-7 FSN 2410-782-1130	48.5	47	2
Tractor, full tracked, 5 ton, universal ballastable, (Universal Engineer Tractor).	36.0	48	2
Tractor, wheeled, industrial: DED, medium dbp, w/bulldozer front:			
Clark Model 290M FSN 2420-088-9384	54.2	77	5
Caterpillar Model 830M FSN 2420-806-0031	54.2	74	5
<i>Cranes and Loaders</i>			
Crane shovel, basic unit, crawler mtd: 2 cu yd 40 ton:			
Baldwin-Lima-Hamilton FSN 3810-230-3821	132.6	59	3
Crane shovel, basic unit, crawler mtd:			
Baldwin-Lima-Hamilton FSN 3810-221-2327	38.2	43	2
Crane shovel basic unit, crawler mtd:			
10 ton $\frac{3}{4}$ cu yd, "UNIT" Model 1020 yd FSN 3810-255-7593	35.0	31	2
Crane shovel, crawler w/catwalk: 2 cu yd, 40 ton, Bucyrus-Erie FSN 3810-263-3068.	132.6	59	3
Crane, revolving, crawler mtd: 30-40 ton, Thew Shovel L-82	103.0	61	4
Crane, wheel mounted: $\frac{3}{8}$ cu yd, 5 ton, DED, 4 x 4, rough terrain, air transportable:			
Koehring Model M7 FSN 3810-828-4457	16.0	89	6
Crane, wheel mounted: 20 ton, $\frac{3}{4}$ cu yd, rough terrain, 4 x 4, FSN 3810-060-2735.	60.5	93	6
Loader, bucket type: full tracked, DED, 3 cu yd per min:			
Haiss Model 77-PC	23.0	56	3

Notes. 1. Items listed include selected standard "A" and "B" and "F" self-propelled vehicles as listed in DA Supply Bulletin 700-20, 31 January 1967. Certain items in final development or undergoing oversea field testing have been included where type classification is pending or is designated "P".

2. The vehicle cone index and category have been calculated from formulas, curves, and tables, as covered in TM 5-330. Weight of vehicle was based on normal design loads, equipment, and crews as would be the conditions under full operational deployment in typical off-the-road movements.

CHAPTER 5

DRAINAGE

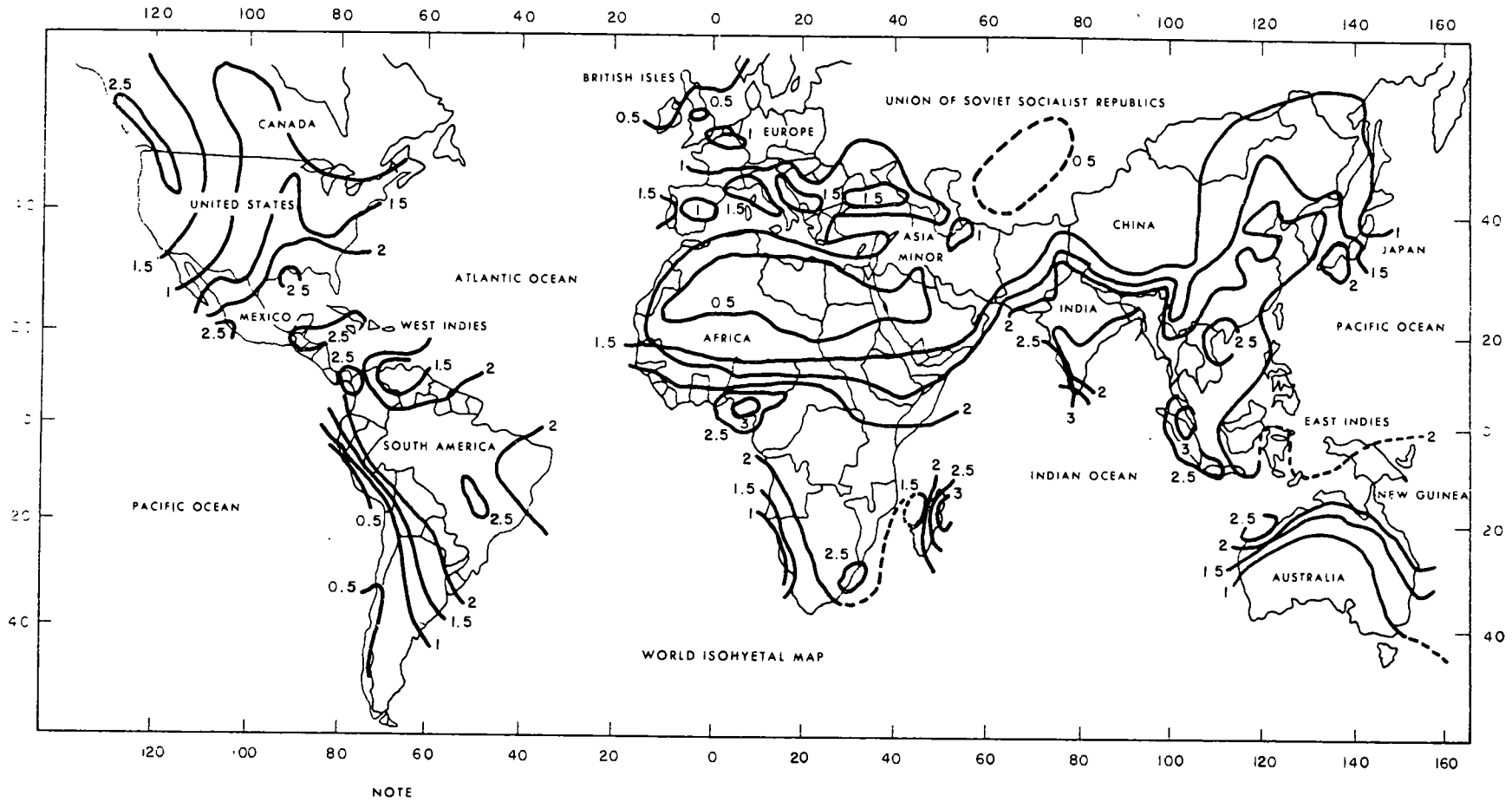
5-1. Introduction

The detailed design of a drainage system is based upon a careful estimate of the quantity of water entering the system at the points of interest. The design rainfall intensity in inches per hour is based upon the relationship between intensity, frequency and duration, infiltration rate, and time of concentration, which are the basic assumptions that must be made. The intensity of rainfall for a particular frequency of occurrence varies greatly with the duration of the rainfall, the average rate for a period of 5 minutes being much higher than the average rate for a period of 1 hour. However, an extensive study of rainfall intensity-frequency data reveals a fairly consistent relationship between the average intensity for 1 hour and for shorter or longer periods of time. Therefore, the common measurement of rate for a particular frequency is in terms of inches per hour for the 1-hour storm. Local rainfall data are most desirable for drainage design, but if not available, standard rainfall-intensity duration curves, and world isohyetal maps, based upon 1 hour periods, are available. The amount of rainfall for periods greater or less than one hour can be estimated therefrom. More complete details on all aspects of drainage are covered in TM 5-330. The U. S. Weather Bureau, appropriate local gov-

ernment agencies and the U. S. Air Force Weather Service may be sources of rainfall data.

5-2. Design Storm

A drainage system is designed on the basis of the most severe rainfall that may be reasonably anticipated during the period of use. A 2-year frequency is used for TO design. In theater of operations, deliberate drainage design is seldom warranted in the battle area, somewhat more frequently in the forward area. For support and rear areas when deliberate design is warranted, the 2-year design storm will be considered as a minimum basis for design as called for by Corp of Engineers requirements. Other design storm frequencies may be specified by higher authority for special locations or problems. Figure 5-1 is a world isohyetal map which gives the rainfall intensity in 1 hour for a 1-hour storm of 2 years' frequency. Table 5-1 gives mean annual and 24-hour maximum rainfall for most areas of the world. Figure 5-2 contains a set of curves that can be used to convert maximum precipitation recorded for a given period of time, to precipitation for the desired design period. Figure 5-3 contains a series of standard rainfall-intensity duration curves which can be used to convert a given rainfall intensity of 1 hour to some other period, such as the time of concentration.



ISOHYETS REPRESENTS INCHES OF MAXIMUM RAINFALL IN ONE HOUR FOR STORM OF 2-YEAR FREQUENCY

Figure 5-1. World isohyetal map.

Table 5-1. Worldwide Precipitation Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years re- corded
ALAKSA														
Barrow:														
Mean	0.15	0.20	0.13	0.12	0.14	0.26	0.89	0.73	0.49	0.56	0.20	0.36	4.23	26
24-hour maximum	.70	.23	.28	.20	.30	.36	.84	.43	1.00	.41	.26	.26	1.00	18-19
Mean snowfall	2.6	2.7	2.0	2.7	1.8	.4	1.0	.7	0.3	7.9	4.3	3.9	33.0	21-23
Ketchikan:														
Mean	13.62	11.16	12.13	10.88	8.39	6.60	8.07	11.61	12.22	20.18	19.96	15.86	150.68	30-32
24-hour maximum	5.87	5.36	5.70	4.44	5.87	4.25	3.34	8.07	6.06	7.04	7.14	5.33	8.07	29-30
Mean snowfall	10.0	7.1	4.7	.6	.4	0	0	0	0	.2	.9	7.4	32.3	-----
Teller (65° 16'N, 166° 20' W.):														
Mean	1.13	.53	.34	.69	.51	.62	1.88	1.48	1.74	.71	.79	.52	10.94	8-13
24-hour maximum	2.10	.58	.35	.70	.80	.50	1.00	1.10	2.20	.50	.72	.55	2.20	6-10
Mean snowfall	12.0	7.1	6.7	6.5	2.4	0	0	0	.2	2.2	7.5	8.2	52.9	5-9
Dutch Harbor:														
Mean	6.32	6.12	4.92	4.19	4.33	2.82	1.89	2.45	5.45	7.39	5.81	6.92	58.61	19-23
24-hour maximum	3.73	3.75	2.47	3.46	2.74	3.00	1.60	2.08	2.53	3.08	3.22	2.31	3.75	19-23
Mean snowfall	15.6	19.7	10.5	6.7	.1	T	0	0	T	.5	5.8	10.8	69.7	19-23
CANADA														
Edmonton, Alberta:														
Mean	.76	.67	.67	.80	1.86	3.26	3.57	2.47	1.40	.74	.73	.75	17.67	-----
24-hour maximum	.70	.80	.60	.83	2.80	2.20	2.16	2.68	1.37	1.03	.80	.70	2.80	15
St. Johns, Newfound- land:														
Mean	5.39	5.08	4.53	4.25	3.54	3.54	3.74	3.58	3.78	5.39	6.06	4.92	53.80	52
Maximum	11.38	12.84	8.84	8.79	7.11	7.83	7.72	9.76	11.42	13.11	12.27	14.05	69.05	57
24-hour maximum	2.44	3.31	1.81	2.99	3.62	2.01	2.28	1.54	2.36	2.80	3.35	3.15	3.62	73
CENTRAL AND SOUTH AMERICA														
Puerto Barrios, Guate- mala (15°35' N., 88°35' W.):														
Mean	11.46	8.86	3.82	3.70	7.99	10.63	16.50	18.62	9.06	7.20	15.47	11.46	124.77	7
Maximum	25.94	26.97	12.43	14.65	18.15	18.15	25.08	29.58	18.54	23.95	32.69	19.93	158.10	19
24-hour maximum	6.75	6.55	5.30	4.69	3.61	4.25	4.94	5.20	6.59	5.55	7.80	11.18	11.18	13
Fortaleza, Brazil (3° 42' S., 38°30' W.):														
Mean	3.35	6.93	11.77	13.46	9.61	4.72	2.13	1.10	.67	.51	.55	1.54	56.34	72
Maximum	18.27	25.12	26.61	32.40	26.14	15.90	10.43	6.61	2.99	3.58	3.78	8.98	109.41	72
24-hour maximum	7.40	7.01	9.61	9.45	5.75	3.50	2.80	2.76	1.57	2.17	1.81	5.20	9.61	59
EUROPE AND ICELAND														
London:														
Mean	1.88	1.57	1.56	1.60	1.75	2.03	2.24	2.23	1.95	2.61	2.28	2.29	23.99	62
Maximum	4.88	4.13	3.94	3.98	4.09	7.20	4.88	6.50	5.71	5.91	3.98	6.38	38.19	68
24-hour maximum	1.6	1.1	.9	1.2	1.8	2.4	2.3	1.8	1.6	1.4	1.3	1.5	2.4	65
Berlin:														
Mean	1.69	1.38	1.57	1.54	1.89	2.36	3.07	2.32	1.69	1.77	1.69	1.89	22.86	80
Maximum	3.94	4.88	5.28	4.17	5.71	5.59	9.06	6.57	4.25	5.28	4.65	4.49	31.61	80
24-hour maximum	.97	.85	.50	1.55	1.27	1.73	2.59	2.66	1.77	.99	1.28	.62	2.66	15
Prague:														
Mean	0.87	0.83	1.10	1.54	2.36	2.76	2.56	2.24	1.65	1.22	1.18	0.94	19.25	70
Maximum	2.36	2.01	2.40	4.33	6.50	6.18	5.67	4.80	5.35	4.17	3.70	3.27	27.52	70
24-hour maximum	.53	.56	.73	1.30	1.28	1.98	2.17	1.57	1.60	1.22	1.13	.80	2.17	15
Budapest:														
Mean	1.46	1.22	1.77	2.28	2.91	2.91	2.09	1.97	2.01	2.60	2.09	1.89	25.20	35
Maximum	3.94	3.11	4.33	3.82	5.51	8.31	7.05	5.04	4.88	5.16	5.79	4.29	37.05	31
24-hour maximum	1.34	1.38	1.26	1.69	1.69	2.20	2.52	3.31	2.44	1.61	1.57	1.50	3.31	30

Table 5-1. Worldwide Precipitation Data—Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years re- corded
EUROPE AND ICE- LAND—Continued														
Helsingfors:														
Mean	1.77	1.46	1.38	1.42	1.77	1.81	2.24	2.91	2.52	2.60	2.48	2.01	24.37	71
Maximum	4.61	3.62	4.45	3.94	4.16	4.61	7.56	6.50	5.91	5.79	5.94	4.76	33.90	87
24-hour maximum	.73	.83	.96	1.46	1.48	1.87	1.82	1.64	2.12	2.12	1.13	1.56	2.12	36
Trondheim:														
Mean	3.43	2.87	2.24	1.81	1.50	1.73	2.24	2.95	3.27	3.39	3.11	2.56	31.10	50
Maximum	11.45	8.80	8.31	6.37	4.07	4.54	4.64	6.40	6.82	8.78	9.95	8.64	56.67	44
24-hour maximum	1.68	1.91	1.96	.99	1.30	1.00	1.66	2.23	1.42	2.24	1.85	2.58	2.58	31
Corfu, Greece:														
Mean	7.72	6.11	4.18	3.70	2.45	1.05	.28	.56	2.82	5.02	7.05	9.54	50.48	38
Maximum	17.13	11.26	9.22	13.35	4.09	4.75	1.14	4.29	6.65	21.50	15.39	13.95	66.75	26
24-hour maximum	5.47	3.23	2.17	2.83	1.85	1.61	1.02	3.35	3.23	5.91	5.08	3.90	5.91	26
Stockholm:														
Mean	.98	.91	1.08	1.07	1.44	1.63	2.37	2.59	1.75	1.98	1.53	1.31	18.64	51
Maximum	3.35	3.90	3.03	3.54	3.31	5.08	7.28	4.84	5.67	6.85	3.15	3.07	28.27	51
24-hour maximum	.53	.84	.81	1.46	1.82	1.26	2.62	2.69	1.66	1.29	1.59	1.14	2.69	38
Reykjavik:														
Mean	3.86	3.31	2.72	2.44	1.89	1.93	1.89	2.01	3.54	3.43	3.74	3.50	34.20	50
Maximum	6.21	9.54	7.21	5.90	2.95	3.64	4.63	6.49	5.99	7.12	6.87	7.35	50.83	19
24-hour maximum	1.30	1.36	2.23	.87	.78	1.16	1.07	1.18	1.07	1.30	1.73	2.17	2.23	19
USSR														
Vladivostok:														
Mean	.5	.6	.8	1.3	2.5	3.5	3.6	5.4	4.8	2.0	1.1	.7	27.8	-----
Maximum	1.5	1.9	4.9	3.0	5.2	7.6	9.2	16.7	13.3	4.7	7.7	1.9	---	38
24-hour maximum	.9	1.3	2.9	1.0	1.7	2.8	3.1	3.6	4.4	2.8	5.2	1.2	5.2	10
Gizhiga (62°02' N., 160°40' E.):														
Mean	.3	.3	.4	.3	.4	.7	1.7	1.8	1.2	1.0	.6	.4	9.1	16
Maximum	1.6	1.0	1.9	.9	1.2	1.5	3.9	3.4	3.0	1.8	1.8	1.6	---	16
24-hour maximum	.4	.4	.8	.6	.4	.6	1.8	.9	.8	1.1	.5	.6	1.8	14
Irkutsk:														
Mean	.39	.29	.28	.24	1.50	2.17	3.46	3.11	1.69	.75	.67	.63	15.51	-----
Maximum	.94	.87	.71	1.38	4.29	6.10	8.90	5.82	4.13	1.85	1.50	2.68	22.68	35
24-hour maximum	.34	.22	.31	.54	1.71	1.94	2.39	2.68	1.35	.81	.51	.31	2.68	30
Odessa:														
Mean	1.00	1.00	.95	.94	1.05	1.98	1.59	.96	.82	1.12	.85	1.11	13.37	18
Maximum	3.98	3.74	2.52	4.02	4.80	6.57	4.65	5.95	5.71	4.21	3.58	3.74	24.88	35
24-hour maximum	1.20	.99	1.36	.85	.85	1.58	2.98	1.28	1.94	2.22	.78	.62	2.98	18
Kola:														
Mean	.50	.84	.49	.62	1.25	1.24	2.27	1.94	1.78	1.26	1.31	.90	14.35	18
Maximum	1.28	2.41	1.11	2.14	2.35	3.18	4.45	4.37	3.52	1.92	2.37	2.48	20.33	18
24-hour maximum	.41	.77	.28	.58	.75	.78	1.07	1.12	.73	.76	.63	.65	1.12	18
Batum:														
Mean	10.07	7.33	5.90	5.84	3.41	6.75	6.30	9.24	11.94	9.47	12.88	10.43	99.56	---
24-hour maximum	2.66	2.14	2.89	2.90	3.87	5.82	5.79	4.07	4.64	4.34	3.36	3.01	5.82	10
Stavropol:														
Mean	1.26	1.14	1.84	2.24	2.91	4.06	3.28	1.69	2.32	1.46	2.13	1.73	25.51	26
Maximum	4.21	2.49	8.66	5.08	6.73	7.80	6.38	4.17	4.65	2.91	4.45	5.63	32.99	26
24-hour maximum	1.43	.58	1.30	1.50	1.29	3.75	3.11	2.35	2.31	1.19	1.17	1.04	3.75	18
Tiflis:														
Mean	.59	.87	1.06	2.32	3.15	2.91	1.77	1.46	2.05	1.57	1.38	.87	20.00	18
24-hour maximum	.54	.61	.75	1.18	2.11	2.65	1.30	1.43	1.91	1.24	1.14	1.80	2.65	18

Table 5-1. Worldwide Precipitation Data—Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years re- corded
ASIA														
Sapporo, Hokkaido:														
Mean	3.5	2.5	2.4	2.2	2.7	2.8	3.3	3.7	5.0	4.6	4.4	4.0	40.9	30
Maximum	8.2	4.6	5.5	5.0	4.9	7.3	8.2	11.2	11.0	11.8	8.3	7.8	53.5	22
24-hour maximum ..	2.8	1.9	1.8	4.2	2.8	4.7	4.9	4.3	4.6	4.0	1.7	2.9	4.9	44
Urakawa, Hokkaido:														
Mean	1.6	.9	2.1	3.1	3.8	3.4	5.1	6.3	4.6	4.4	4.2	2.1	41.8	6
Maximum	2.6	1.6	2.6	5.5	5.3	7.4	15.8	9.1	6.1	5.7	7.0	2.7	55.2	6
24-hour maximum ..	1.0	.6	1.1	1.4	1.8	2.0	5.8	3.5	2.4	2.6	2.0	1.1	5.8	6
Kobe, Honshu:														
Mean	1.9	2.2	3.6	5.0	4.9	8.2	6.0	4.6	7.7	4.8	2.6	1.8	53.3	-----
Maximum	3.4	5.9	6.5	8.5	9.8	14.8	11.8	9.6	6.6	10.8	6.0	3.9	65.6	-----
24-hour maximum ..	1.6	2.3	2.5	2.6	3.4	5.9	4.6	4.6	7.8	3.9	2.7	1.8	7.8	-----
Hamada, Honshu:														
Mean	4.5	3.9	4.6	5.0	4.9	7.7	7.5	4.6	8.2	5.1	4.2	4.6	64.8	-----
Maximum	6.9	7.3	7.1	8.6	9.6	22.3	18.6	12.0	20.0	10.9	7.5	9.1	92.5	-----
24-hour maximum ..	2.0	2.6	2.0	2.5	3.9	4.3	8.0	8.9	5.4	3.3	1.9	2.2	8.9	-----
Gensan, Korea:														
Mean	1.20	1.47	1.78	2.76	3.41	4.74	10.46	12.09	7.02	3.33	2.50	1.39	52.15	21
Maximum	3.26	5.11	5.33	7.08	5.90	12.26	16.33	21.33	16.43	17.94	5.65	7.07	79.89	21
24-hour maximum ..	2.9	2.9	3.8	4.6	5.0	4.8	6.9	7.7	9.6	8.8	3.4	3.3	9.6	29
Yunnan (25°07' N., 102°54' E.):														
Mean	.35	.55	.67	.75	4.21	6.22	8.74	8.58	4.96	2.91	1.81	.43	40.18	32
Maximum	2.17	2.32	2.91	2.80	12.68	22.56	18.11	15.67	11.61	7.56	6.85	1.81	61.02	32
24-hour maximum ..	1.22	1.06	1.26	1.14	2.60	9.61	4.29	4.49	4.53	2.80	2.87	1.30	9.61	32
Honkong, China:														
Mean	1.27	1.75	2.93	5.44	11.50	15.52	15.01	14.22	10.11	4.55	1.70	1.15	85.16	53
Maximum	8.43	7.94	11.48	17.16	48.84	34.38	30.08	34.31	30.60	23.98	8.82	4.90	119.72	47
24-hour maximum ..	3.92	2.18	3.78	6.22	20.50	12.63	21.02	11.14	7.96	11.50	5.88	3.58	21.02	53
Tientsin:														
Mean	.16	.09	.37	.63	1.13	2.46	7.00	5.50	1.76	.59	.39	.15	20.23	44
Maximum	.91	.62	1.73	1.89	2.28	6.96	14.46	11.39	5.26	1.64	1.89	.46	28.70	20
24-hour maximum ..	.64	.50	1.37	1.22	1.90	3.09	4.77	4.89	2.31	1.26	1.13	.28	4.89	22
Urga (47°55' N., 106° 50' E.):														
Mean	.04	.03	.06	.22	.34	.96	2.91	1.91	.76	.20	.15	.10	7.68	15
Maximum	.16	.13	.37	.79	1.35	3.40	6.47	4.33	2.09	.66	1.38	.89	13.69	15
24-hour maximum ..	.09	.06	.17	.31	.67	1.07	2.86	2.38	1.61	.33	.69	.69	2.86	10
Singapore:														
Mean	9.88	6.62	7.40	7.64	6.65	6.85	6.77	7.95	6.77	8.07	9.92	10.55	95.07	52
Maximum	14.13	24.98	19.74	14.92	10.79	14.08	13.56	10.81	17.26	12.06	15.15	16.91	14.03	21
24-hour maximum ..	6.93	4.30	4.88	2.97	4.92	3.46	3.91	4.17	5.20	6.02	4.02	4.35	6.93	21
Dairen, Manchuria:														
Mean	.5	.3	.7	1.0	1.7	1.8	6.4	5.1	4.0	1.1	1.0	.5	24.1	25
Maximum	1.9	1.1	8.5	2.6	4.3	3.3	16.0	15.3	12.7	2.3	2.7	.9	44.3	19
24-hour maximum ..	1.4	1.1	1.8	1.9	2.2	2.7	7.5	6.4	4.1	1.5	1.8	.6	7.5	25
Manchouli:														
Mean	0.1	0.1	0.1	0.1	0.6	1.7	2.9	2.4	1.3	0.3	0.2	0.1	9.9	20
Maximum	.4	.2	.5	.7	2.3	4.3	6.1	5.6	3.3	1.5	.6	.4	14.4	20
24-hour maximum ..	.1	.1	.3	.4	1.3	1.9	1.1	2.3	1.4	1.0	.5	.2	2.3	7
Aden, Arabia:														
Mean	.3	.2	.4	.2	.1	.1	.03	.1	.1	.1	.1	.1	1.8	-----
Maximum	3.31	1.58	6.57	3.87	1.40	1.34	.62	1.97	1.36	2.23	1.28	1.55	8.57	-----
24-hour maximum ..	2.2	1.4	3.0	2.6	1.4	1.0	.6	1.4	1.3	2.2	.8	1.1	3.0	-----
Cherrapunji, India:														
Mean	.45	2.72	9.38	28.19	46.28	95.92	98.51	79.84	37.98	21.26	3.23	.31	424.07	20
Maximum	8.07	5.39	19.65	52.05	128.57	169.92	147.44	97.83	99.41	51.73	14.02	9.61	560.27	20
24-hour maximum ..	1.12	1.32	2.80	10.20	16.90	36.40	21.08	22.61	24.66	21.62	3.23	.15	36.40	5

Table 5-1. Worldwide Precipitation Data—Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years re- corded
ASIA—Continued														
Karachi:														
Mean	.48	.36	.21	.11	.06	.57	3.10	1.65	.65	.02	.13	.20	7.58	83
Maximum	3.38	2.94	3.83	4.75	1.85	10.59	18.63	14.15	15.35	1.56	4.66	2.58	28.00	83
24-hour maximum	.39	1.15	.21	.70	.15	2.04	7.86	5.41	8.11	.52	.86	1.83	8.11	18
Trichinopoly, India:														
Mean	.96	.48	.40	1.79	3.18	1.48	1.47	3.88	4.65	7.08	5.54	2.77	33.68	61
Maximum	8.02	3.06	1.26	7.88	10.76	3.66	3.30	9.61	10.80	27.43	13.68	12.98	51.11	18
24-hour maximum	4.32	1.86	.67	3.74	7.21	1.87	2.12	3.81	3.26	12.56	6.21	5.34	12.56	18
AFRICA														
Casablanca:														
Mean	2.03	1.98	2.37	1.24	.78	.22	.00	.01	.42	1.21	2.76	2.59	15.61	22
Maximum	4.71	4.92	7.02	3.96	2.62	.89	.01	.16	2.19	4.68	7.26	7.69	21.28	28
24-hour maximum	1.14	1.13	.76	1.24	3.01	.26	.11	.04	1.80	1.27	2.54	2.58	3.01	10
Huambo, Angola:														
Mean	8.71	8.87	8.42	6.06	1.08	0	0	.09	.82	5.14	8.94	9.48	57.61	6
Maximum	17.40	19.87	12.02	10.93	6.93	0	0	.36	2.48	10.53	12.38	14.93	87.00	6
24-hour maximum	1.31	1.04	1.50	1.20	.28	---	---	---	.49	3.04	2.43	2.63	---	2
Cairo:														
Mean	.24	.16	.20	.08	.08	.04	0	0	0	.08	.08	.20	1.16	26
Maximum	1.14	.63	1.02	.47	.51	.08	0	0	0	.55	.59	1.06	2.48	21
24-hour maximum	1.70	.61	.85	.81	1.11	.52	0	0	0	.57	.38	1.15	1.70	26
NEW ZEALAND, AUSTRALIA, AND NEW GUINEA														
Finschafen, New Guinea 6°03' S, 147°52' E.):														
Mean	3.13	4.02	3.94	8.56	13.60	17.44	17.62	19.82	13.43	14.70	9.36	4.61	130.23	15
Maximum	7.56	10.59	8.31	17.66	29.64	29.09	29.61	35.43	31.58	41.61	23.23	12.36	181.22	15
24-hour maximum	2.11	4.17	2.64	8.82	6.88	5.83	9.57	6.73	7.44	19.65	7.83	4.49	19.65	---
Darwin, Australia:														
Mean	15.83	12.87	9.88	4.17	.67	.16	.08	.12	.51	2.17	4.88	10.39	61.73	52
Maximum	27.86	22.65	21.88	23.74	10.27	1.53	2.56	3.00	2.31	6.28	14.57	22.38	87.22	58
24-hour maximum	11.65	5.12	7.17	4.25	1.18	1.34	1.69	1.06	1.97	3.58	2.76	7.87	11.65	28
Daly Waters, Austral- ia:														
Mean	6.21	6.45	4.79	1.00	.16	.32	.06	.14	.27	.83	2.06	4.08	26.37	43
Maximum	23.16	13.22	14.50	4.39	.28	.46	.56	0	.93	1.42	10.42	15.76	43.25	12
24-hour maximum	1.74	3.25	2.80	2.78	0	.11	.28	0	.79	.30	1.34	3.60	3.60	3
Brisbane:														
Mean	6.5	5.4	5.7	8.9	2.8	2.7	2.2	2.0	2.0	2.5	3.8	4.9	45.4	83
Maximum	27.72	40.39	34.04	15.28	13.85	14.03	8.46	14.67	5.43	9.99	12.40	13.99	88.26	91
24-hour maximum	18.3	10.6	11.2	5.5	5.6	6.0	3.5	4.9	2.5	3.7	4.5	6.6	18.3	63
Wellington:														
Mean	3.30	3.19	3.29	3.80	4.76	4.87	5.55	4.43	3.99	4.19	3.44	3.30	48.11	69
Maximum	10.13	8.89	9.94	12.15	11.80	9.53	12.17	9.88	11.05	12.94	9.99	12.46	67.68	69
24-hour maximum	4.50	6.30	5.70	4.90	5.70	3.00	3.10	3.70	3.80	3.50	2.70	3.50	6.30	63
ARCTIC (not included previously)														
Jan Mayen (70°59' N., 8°20' W.):														
Mean	1.54	1.69	1.10	.94	.51	.59	.79	1.06	2.52	2.20	1.42	.98	15.34	7
Maximum	3.41	4.09	3.03	3.07	1.41	1.82	4.05	4.05	4.75	4.80	3.66	4.14	---	16
Coopermine:														
Mean	.44	.56	.78	.82	.52	.86	1.34	1.76	1.19	1.01	.80	.53	10.46	5
Maximum	.74	2.10	1.95	3.45	.89	2.34	1.84	3.20	1.95	2.23	2.20	.90	---	7
Mean snowfall	3.5	5.6	7.3	6.8	3.9	2.9	.1	.4	4.7	9.1	8.6	5.3	58.2	---

Table 5-1. Worldwide Precipitation Data—Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years re- corded
ARCTIC—Continued														
Uelen, Siberia:														
Mean	.63	.56	.39	.49	.43	.50	1.61	1.79	2.09	1.85	.54	.96	11.84	8
Maximum	2.28	1.85	.67	.98	1.08	.94	2.11	2.64	4.70	6.18	.88	2.38	-----	8
Average thickness of snow cover at Anadyr.	12.8	17.6	20.3	21.5	17.7	1.8	-----	-----	.1	1.7	4.6	8.5	-----	-----
ANTARCTIC														
Little America:														
1929 snowfall (un- melted depths in inches).	7.3	12.7	24.2	5.6	7.6	16.2	8.9	11.3	2.4	2.0	2.9	2.3	103.5	1

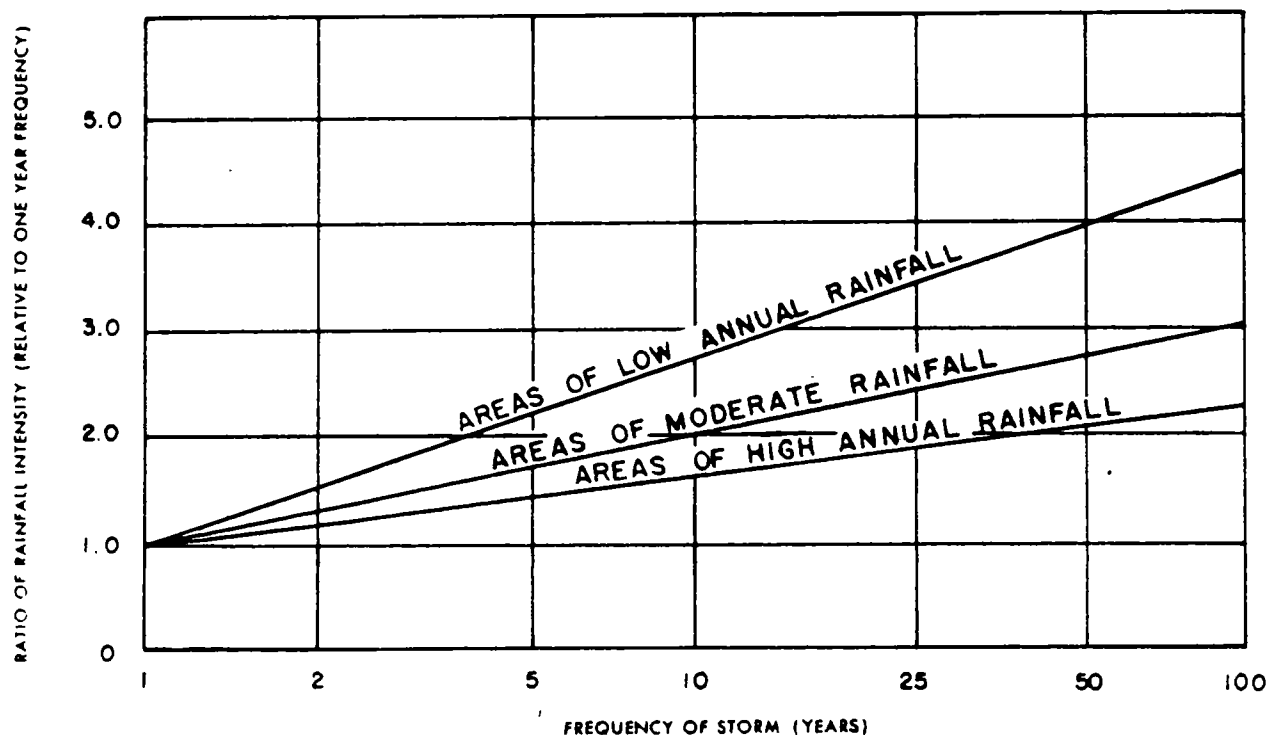
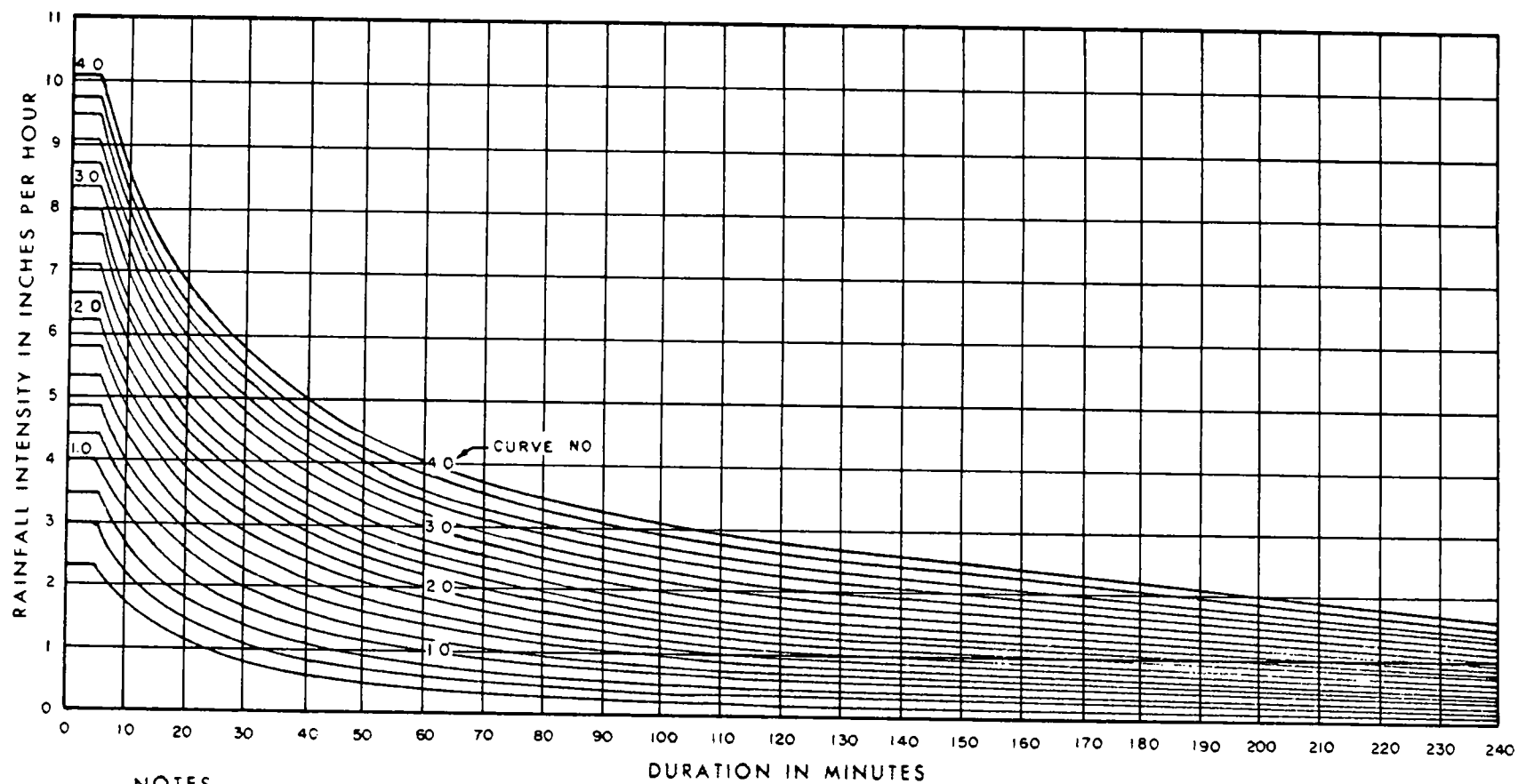


Figure 5-2. Rainfall intensity related to frequency of storms.



NOTES:

1. Curve numbers correspond to one-hour values of rainfall or supply indicated by respective curves.
2. All points on the same curve are assumed to have the same average frequency of occurrence

Figure 5-3. Standard rainfall-intensity duration curves.

Example 1. If rainfall data are available for 50 years in an area of high normal rainfall, the maximum 24-hour rainfall is 10 inches, and the design storm to be used is of 2-year frequency, enter figure 5-2 at 50 years, move vertically to the curve designated "areas of high annual rainfall", and determine a conversion factor of 2.05. Next, enter the figure at the desired design storm of 2 years, move vertically to the same curve, and determine a conversion factor of 1.18. Then

$\frac{1.18}{2.05} \times 10 \text{ in.} = 5.8 \text{ inches}$, the approximate 24-hour maximum for a 2-year frequency. A factor of 0.40 is used to convert the 24-hour rainfall to a 1-hour rainfall. Therefore 5.8×2.32 inches per hour. The same procedure can be followed in determining rainfall intensities for other periods of time.

Example 2. Consider that the 2.32 inches is maximum rainfall in 1 hour for a 2 year frequency, and that the time of concentration (TOC) is 30 minutes. Enter figure 5-3 at duration 30 minutes, read up to supply curve 2.32 (interpolate between 2.2 and 2.4), read horizontally to left and determine a rainfall intensity of 3.6 inches per hour for a 30-minute period. If local rainfall data are inadequate, maximum rainfall for a period of 1 hour for a storm of 2-year frequency can be read from figure 5-1, and the same procedure followed. Method for estimating TOC is covered in paragraph 5-3.

5-3. Runoff Determination

In addition to the design storm, other factors which influence quantity of water to be handled in a drainage system are infiltration rate and time of concentration (TOC). Infiltration rate is the rate at which the earth absorbs water during the storm. It is stated in inches per hour. Table 5-2 gives infiltration rates for the various soils as classified under the Unified Soil Classification System. Time of concentration is defined as time of overland flow plus time of flow in the drainage system, from the point where overland flow ceases, to point being investigated. Time of overland flow is defined as the time required for a particle of water to travel from the most remote point in the drainage area to the point where it enters the drainage system. Figure 5-4 gives time of overland flow for various conditions. To read time of concentration (TOC) from figure 5-4, you must know the distance of overland flow, average ground slope for path of flow, and surface type. As an example, assume a flow distance of 800 feet over sparse turf on 2.0 percent slope.

5-4. Drainage Structure Opening Requirement

The Hasty Method and Talbot's formula are the most common methods used in the theater of operations for determining the area of waterway opening required. The Rational method is used to estimate runoff, or the quantity of water flowing past any point in a given time. The Corps of Engineers method of determining runoff is more precise, takes more time, and is normally used only where permanent construction is involved. It is explained in detail in TM 5-330.

a. Hasty Method. By field inspection determine high water mark in ditch or gully in which drainage structure is to be built. Calculate cross-sectional area as indicated in figure 5-5 and multiply by 2 for safety factor.

b. Talbot's Formula. The formula is; $A = C \sqrt{D^3}$, where:

A = area of waterway opening in square feet

C = a coefficient that is determined from slope, shape, and character of drainage area

D = drainage area in acres

The key to the use of this formula is in choice of value for coefficient C . Normal values are defined as follows:

$C = 0.2$ for flat areas not affected by accumulated snow, and where the length of the valley drained is several times the width.

$C = 0.5$ for gently rolling farmland.

$C = 0.7$ for rough hilly areas having moderate slopes.

$C = 1.0$ for steep barren areas having abrupt slopes, and for moderately mountainous areas.

A nomograph for rapid solution of Talbot's formula is given in figure 5-6.

Talbot's formula is not recommended for waterway openings of over 400 square feet or where rainfall intensity exceeds 4 inches per hour for 1 hour or less.

c. Rational Method. The formula is $Q = CIA$, where:

Q = runoff from a given area in cubic feet per second.

C = a coefficient representing the ratio of runoff to rainfall.

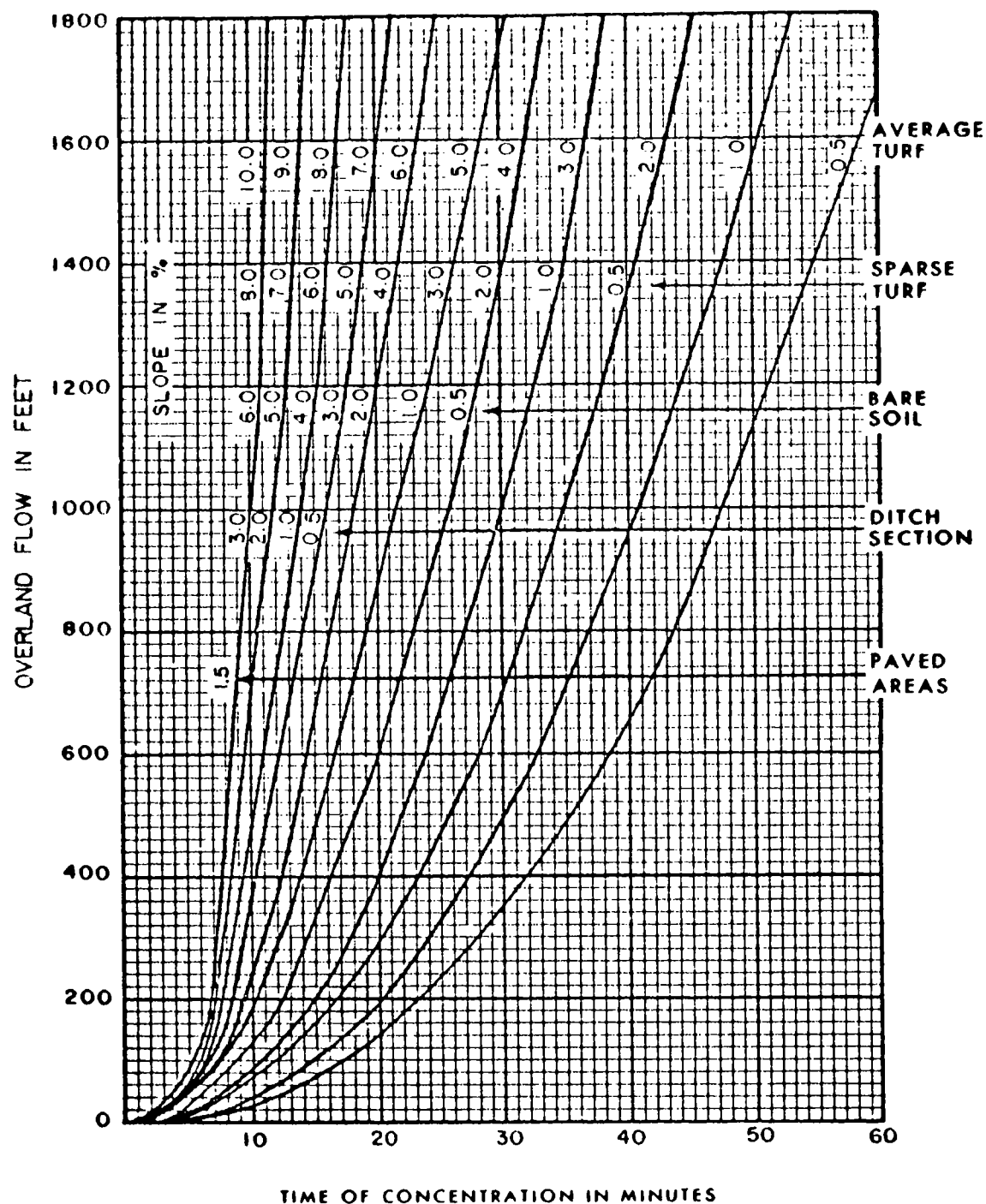


Figure 5-4. Curves for time of overland flow.

Table 5-2. Infiltration Rates, Inches per Hour

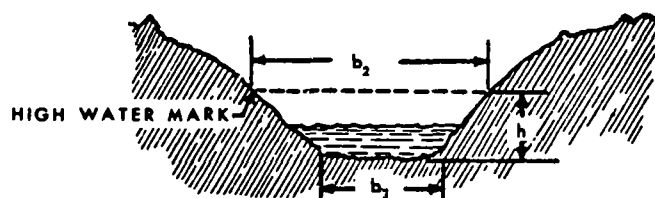
Major divisions		Symbol		Dense cover	Average cover	Sparse cover
Coarse grained	Gravel and gravelly soils	GW		1.0–1.5	0.8–1.2	0.6 –1.0
		GP		1.0–1.5	0.8–1.2	0.6 –1.0
		GM	d	1.0–0.8	0.4–0.6	0.2 –0.4
			u	0.4–0.5	0.3–0.4	0.2 –0.3
	GC		0.3–0.4	0.2–0.3	0.1 –0.2	
	Sand and sandy soils	SW		1.0–1.5	0.8–1.2	0.6 –1.0
		SP		1.0–1.5	0.8–1.2	0.6 –1.0
		SM	d	1.0–0.8	0.4–0.6	0.2 –0.4
			u	0.4–0.5	0.3–0.4	0.2 –0.3
		SC		0.3–0.4	0.2–0.3	0.1 –0.2
Fine grained	Silts and clays LL > 50	CL		0.1–0.2	0.1–0.2	0.02–0.1
		ML		1.0–0.8	0.4–0.6	0.2 –0.4
		OL		0.6–0.8	0.4–0.6	0.2 –0.4
	Silts and clays LL < 50	CH		0.1–0.2	0.1–0.2	0.02–0.1
		MH		0.6–0.8	0.4–0.6	0.2 –0.4
		OH		0.1–0.2	0.1–0.2	0.02–0.1
		PT		0.6–0.8	0.4–0.6	0.2 –0.4

Note. For pavements use zero. A very high water table will reduce infiltration capacity, particularly in coarse grained soils.

I = intensity of rainfall in inches per hour for the estimated time of concentration.

A = drainage area in acres.

Table 5-3 gives a range of values for C commonly used with the rational method.



b_1 = width of channel at bottom

b_2 = width of channel at high water mark

h = vertical distance from bottom of channel to high water mark

$$\text{Area of waterway} = \frac{(b_1 + b_2) h}{2}$$

$$\text{Size of culvert} = \text{area of waterway} \times 2$$

Figure 5-5. Determining size of drainage structure by the Hasty Method.

5-5. Surface Drainage Structures

Underground drainage systems are seldom justified in theater of operations construction, so will not be included here. TM 5-330 covers subsurface drainage. Open channels and culverts are the most common drainage structures used because of their relatively low cost and flexibility. Open channels, or ditches, may be classified as triangular, trapezoidal, or segmental. Figure 5-7 illustrates these shapes and gives useful data for ditches of various depths and side slopes. Safety, operational requirements, stability of the soil, construction equipment available, and proposed maintenance methods are the primary considerations in determining shape, side slope, and depth of channel. However, for discharges exceeding 60 cfs, the trapezoidal section is recommended. The hydraulic characteristics of open channels may be studied by the use of Manning's equation:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \text{ where,}$$

V = mean velocity in feet per second (fps)

S = longitudinal slope in feet per foot

R = hydraulic radius in feet

n = Manning's coefficient of roughness

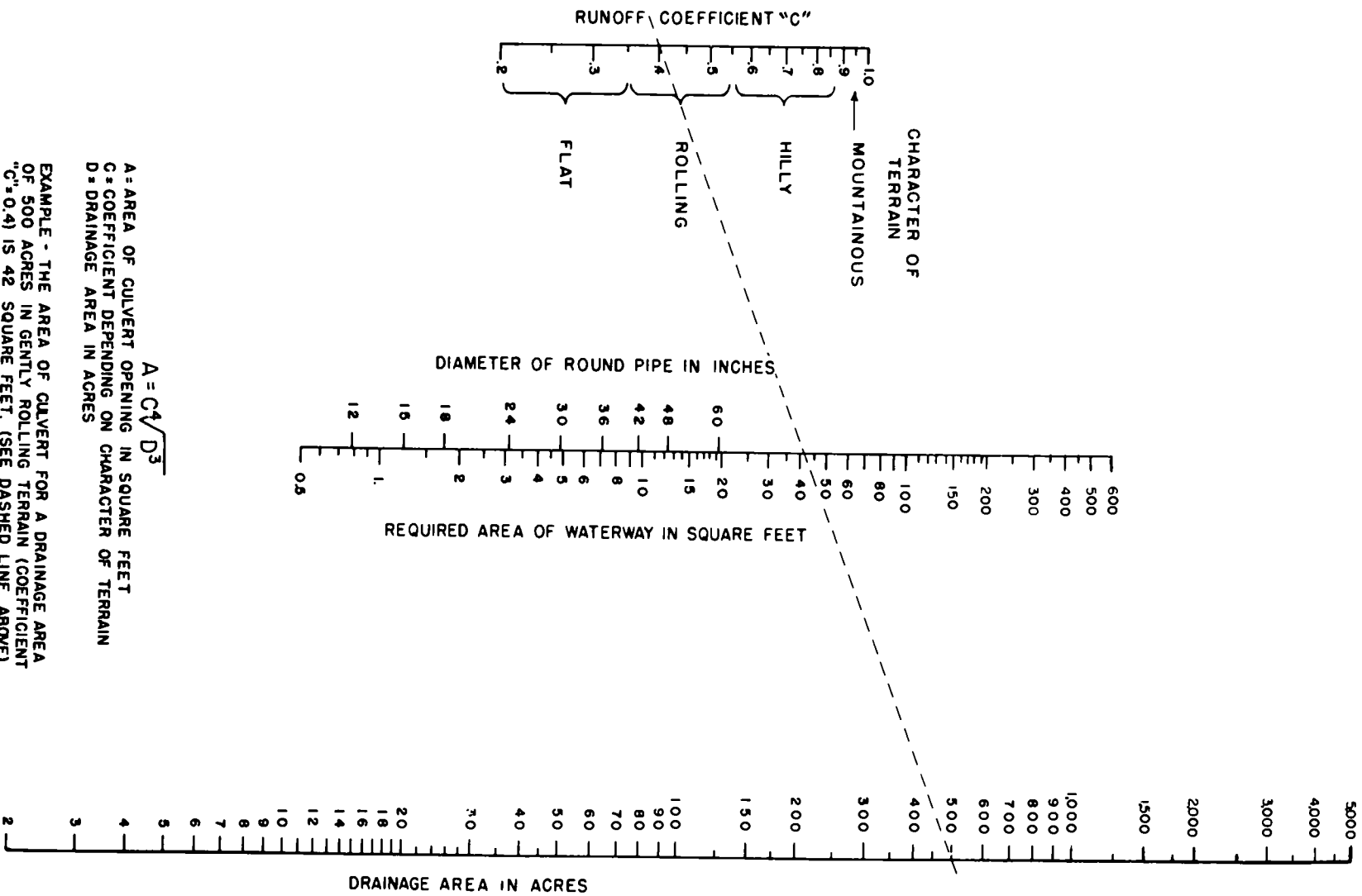


Figure 5-6. Nomograph for solution of Talbot's formula.

Table 5-3. Surface Runoff Coefficients

Types of surface	Coefficients
Pavements (concrete or asphalt)	0.70 to 0.95.
Gravel or macadam pavements	0.35 to 0.70.
Impervious soils ¹	0.40 to 0.65.
Impervious soils, with turf ¹	0.30 to 0.55.
Slightly pervious soils ¹	0.15 to 0.40.
Pervious soils ¹	0.01 to 0.10.
Wooded areas depending on surface slope and soil cover	0.01 to 0.20.

¹ For slopes from 1 to 2 percent.

Note. The figures given are for comparatively level ground. For slopes greater than 1 in 50 (2%) the coefficient should be increased by 0.2 for every 2 percent of slope, but coefficient cannot exceed 1.0.

Table 5-4 gives values for "n" and maximum velocity in fps for soils as classified under the Unified Soil Classification System. Figure 5-8 is a nomograph for solving channel flow problems by Manning's formula. Figure 5-9 is to be used for very flat, shallow, triangular channels.

Table 5-4. Values for Manning's n and Maximum Permissible Velocity of Flow in Open Channels

Ditch lining				Manning's n	V max fps
1. Natural earth					
a. Without vegetation					
(1) Rock.					
(a) Smooth and uniform				0.035-0.040	20
(b) Jagged & irregular				0.040-0.045	15-18
(2) Soils					
Coarse grained	Gravel and gravelly soils	GW		0.022-0.024	6-7
		GP		0.023-0.026	7-8
		GM	d	0.023-0.025	3-5
			u	0.022-0.020	2-4
		GC		0.024-0.026	5-7
	Sand and sandy soils	SW		0.020-0.024	1-2
		SP		0.022-0.024	1-2
		SM	d	0.020-0.023	2-3
			u	0.021-0.023	2-3
		SC		0.023-0.025	3-4
Fine grained	Silts and clays	50	CL	0.022-0.024	2-3
		LL	ML	0.023-0.024	3-4
		LL	OL	0.022-0.024	2-3
		50	CH	0.022-0.023	2-3
			MH	0.023-0.024	3-5
		LL	OH	0.022-0.024	2-3
		PT		0.022-0.025	2-3
Highly Organic					
b. With vegetation					
(1) Average turf					
(a) Erosion resistant soil				0.050-0.070	4-5
(b) Easily eroded soil				0.030-0.050	3-4
(2) Dense turf					
(a) Erosion resistant soil				0.070-0.090	6-8
(b) Easily eroded soil				0.040-0.050	5-6
(3) Clean bottom with bushes on sides				0.050-0.080	4-5
(4) Channel with tree stumps					

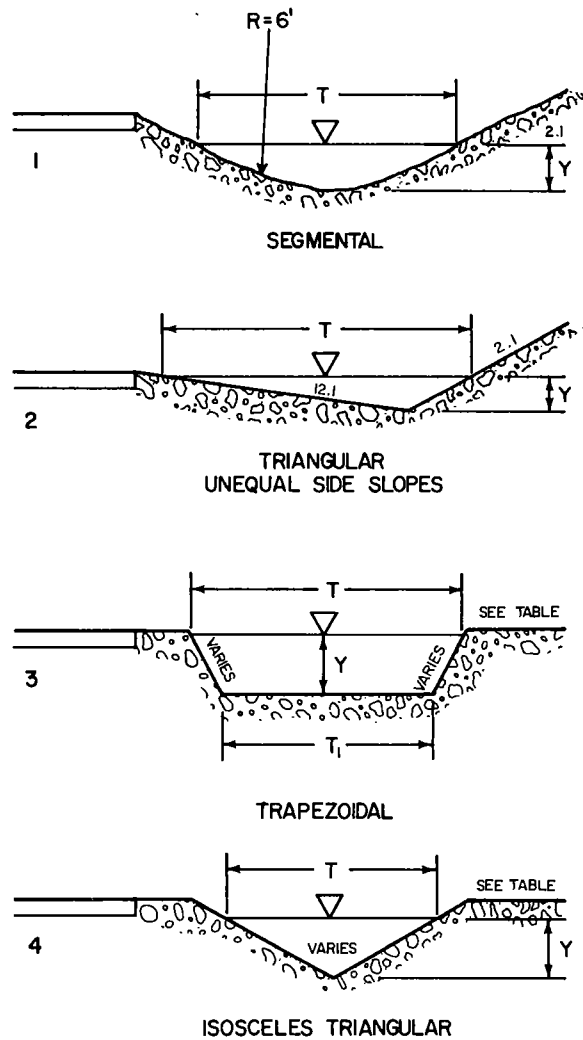
Table 5-4. Values for Manning's *n* and Maximum Permissible Velocity of Flow in Open Channels—Continued

Ditch lining	Manning's <i>n</i>	<i>V</i> max fps
(a) No sprouts	0.040-0.050	5-7
(b) With sprouts	0.060-0.080	6-8
(5) Dense weeds	0.080-0.120	5-6
(6) Dense brush	0.100-0.140	4-5
(7) Dense willows	0.150-0.200	8-9
2. Paved	(Construction)	
a. Concrete, w/all surfaces:	Good Poor	<i>V</i> max fps
(1) Trowel finish	0.012-0.014	20
(2) Float finish	0.013-0.015	20
(3) Formed, no finish	0.014-0.016	20
b. Concrete bottom, float finished, w/sides of:		
(1) Dressed stone in mortar	0.015-0.017	18-20
(2) Random stone in mortar	0.017-0.020	17-19
(3) Dressed stone or smooth concrete rubble (riprap)	0.020-0.025	15
(4) Rubble or random stone (riprap)	0.025-0.030	15
c. Gravel bottom, sides of:		
(1) Formed concrete	0.017-0.020	10
(2) Random stone in mortar	0.020-0.023	8-10
(3) Random stone or rubble (riprap)	0.023-0.033	8-10
d. Brick	0.014-0.017	10
e. Asphalt	0.013-0.016	18-20

Size of culvert opening required may be determined by methods outlined in paragraph 5-4. Corrugated metal pipe (CMP) is the most common type used in the theater of operations. It is a standard issue item in sizes 12-inch to 48-inch diameter in 6-inch increments, and 60-inch and 72-inch diameters. Concrete pipe may be procured locally or manufactured in the field, and culverts may also be improvised from oil drums, timber, logs, etc. Figures 5-10 through 5-12 illustrate some of the principles of good culvert installation. If permanent headwalls and aprons are not installed, riprap should be used to prevent loss of,

or damage to the culvert installation. Desirable culvert grades are 2 to 4 percent. Figure 5-13 illustrates several types of headwalls that can be constructed to prevent erosion. Figures 5-14 and 5-15 illustrate cradles and spread footings that can be used when the bearing strength of the soil is inadequate. Table 5-5 gives minimum pipe cover for various type pipes and wheel loadings for airfields and heliports. As a general rule, the minimum cover for road culverts is 12 inches or one-half the pipe diameter, whichever is greater. Maximum cover for CMP is given in tables 5-6 and 5-7.

DRAINAGE DITCHES - COMMON SECTIONS



PROPERTIES OF DITCHES								
No.	DIMENSIONS				HYDRAULICS			
	Side Slopes	T ₁	Y	T	A	WP	R	R ^{2/3}
1	-	-	6½"	5'-0"	1.84	5.16	0.356	0.502
2	12:1&2:1	-	6"	7'-0"	1.75	7.14	0.245	0.392
3-A	1½:1	2'-0"	1'-0"	5'-0"	3.50	5.61	0.624	0.730
B	2:1	2'-0"	1'-0"	6'-0"	4.00	6.47	0.618	0.726
C	3:1	2'-0"	1'-0"	8'-0"	5.00	8.32	0.601	0.712
D	1½:1	3'-0"	1'-6"	7'-6"	7.88	8.41	0.937	0.958
E	2:1	3'-0"	1'-6"	9'-0"	9.00	9.71	0.927	0.951
F	3:1	3'-0"	1'-6"	12'-0"	11.25	12.49	0.901	0.933
G	1½:1	3'-0"	2'-0"	9'-0"	12.00	10.21	1.175	1.114
H	2:1	3'-0"	2'-0"	11'-0"	14.00	11.94	1.173	1.112
I	3:1	3'-0"	2'-0"	15'-0"	18.00	15.65	1.150	1.097
J	1½:1	4'-0"	3'-0"	13'-0"	25.50	14.82	1.721	1.436
K	2:1	4'-0"	3'-0"	16'-0"	30.00	17.42	1.722	1.437
L	3:1	4'-0"	3'-0"	22'-0"	39.00	22.97	1.698	1.423
4-A	2:1	-	1'-0"	4'-0"	2.00	4.47	0.447	0.584
B	3:1	-	1'-0"	6'-0"	3.00	6.32	0.475	0.609
C	2:1	-	2'-0"	8'-0"	8.00	8.94	0.895	0.929
D	3:1	-	2'-0"	12'-0"	12.00	12.65	0.949	0.965
E	2:1	-	3'-0"	12'-0"	18.00	13.42	1.341	1.216
F	3:1	-	3'-0"	18'-0"	27.00	18.97	1.423	1.265
G	7:1	-	1'-0"	14'-0"	7.00	14.14	0.495	0.626
H	7:1	-	2'-0"	28'-0"	28.00	28.28	0.990	0.993
I	7:1	-	3'-0"	42'-0"	63.00	42.43	1.485	1.302

Where: T₁ - Width of bottom

Y - Depth of flow

WP - Wetted perimeter

R - Hydraulic radius

T - Width of ditch at elevation of flow

A - Area of ditch flow

Figure 5-7. Drainage ditches—common sections.

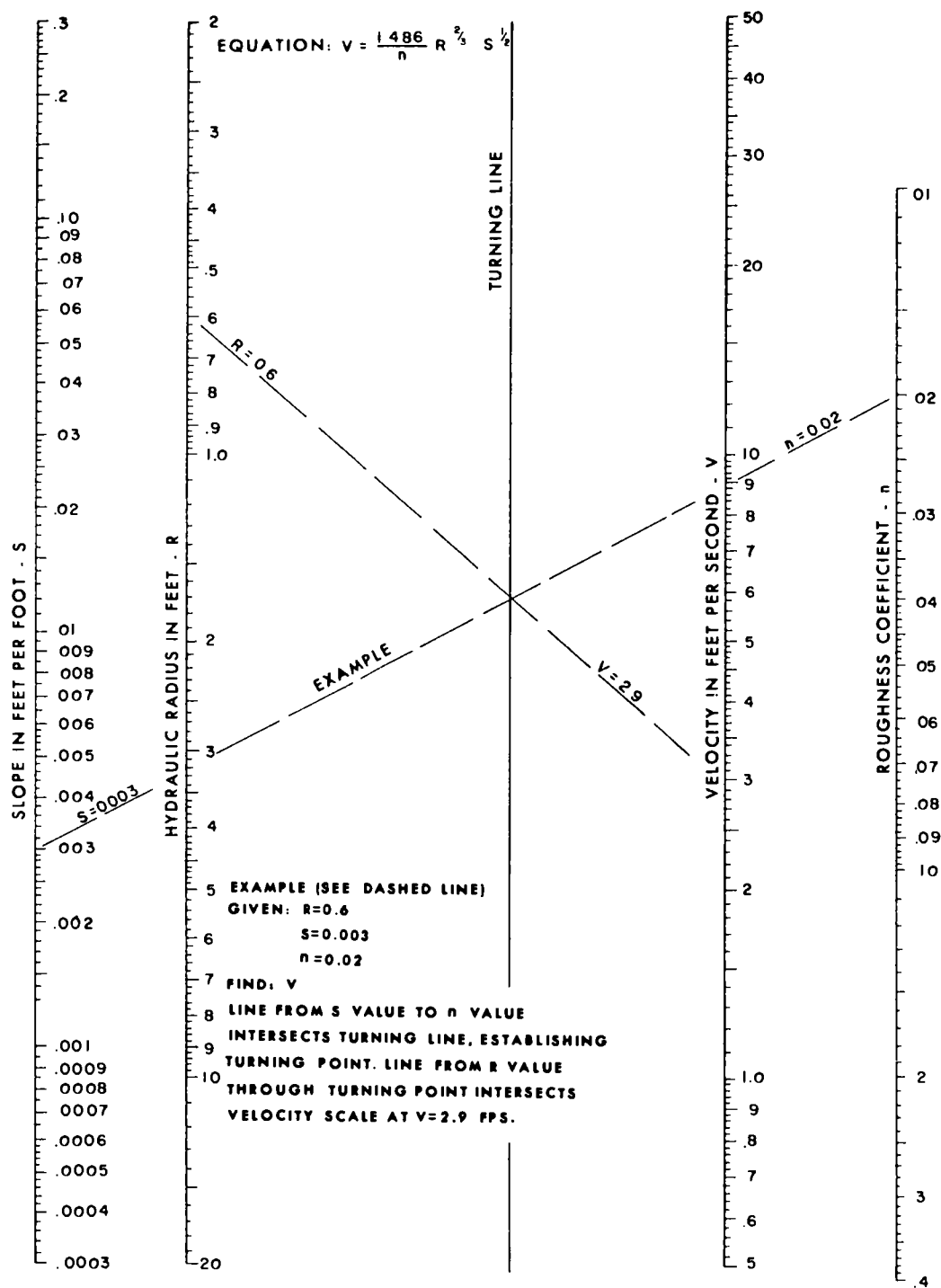


Figure 5-8. Nomograph for Manning's formula.

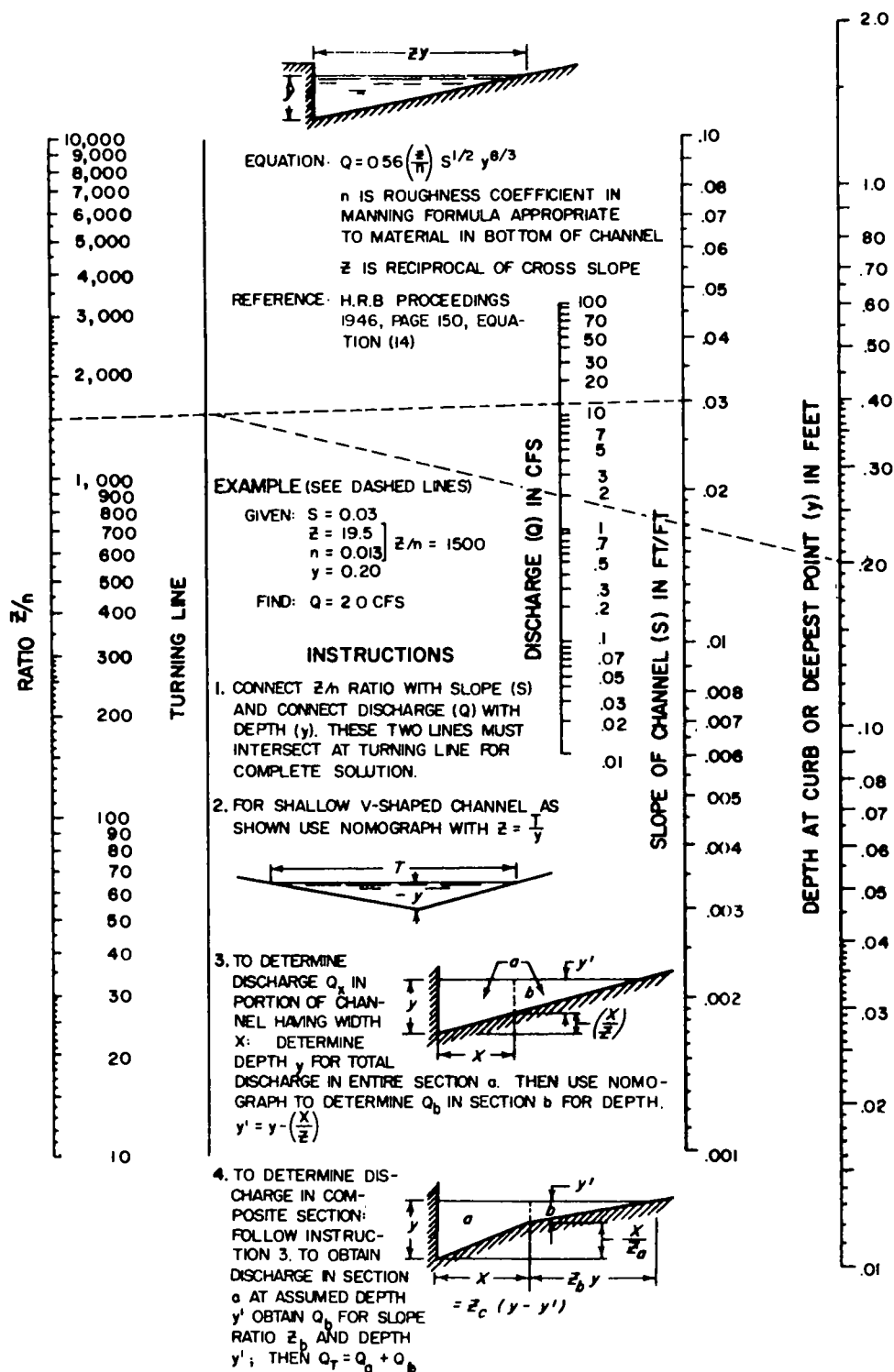


Figure 5-9. Nomograph for flow in shallow triangular channels.

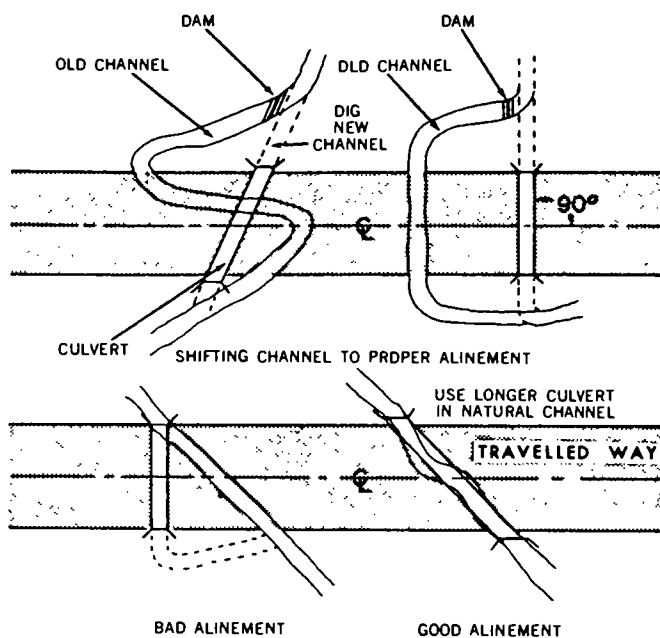


Figure 5-10. Alinement of culverts.

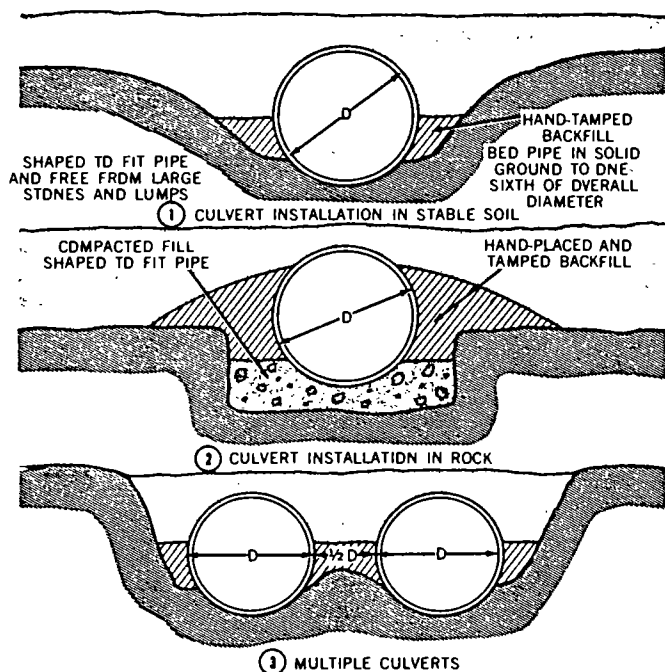


Figure 5-11. Culvert installation.

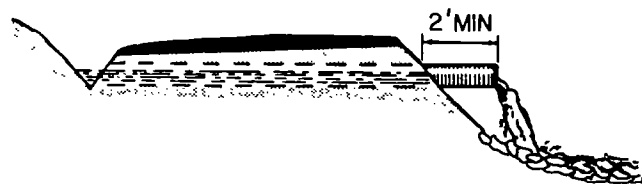
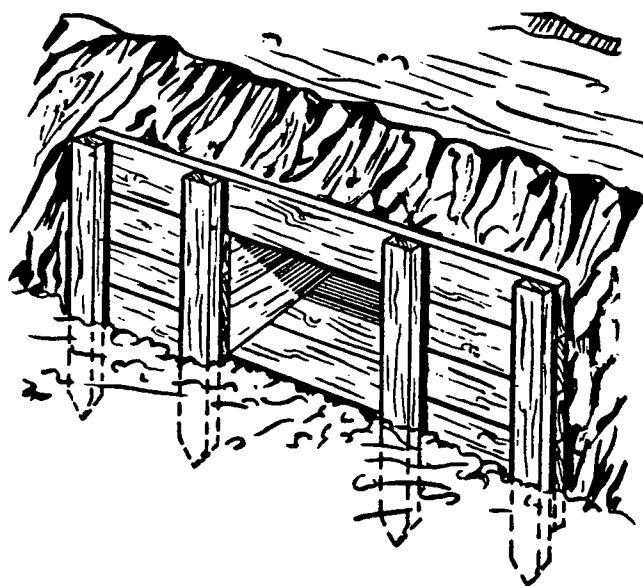


Figure 5-12. Culvert extended beyond fill to reduce erosion.



①

PLANK HEADWALL

Figure 5-13. Headwalls for culverts.

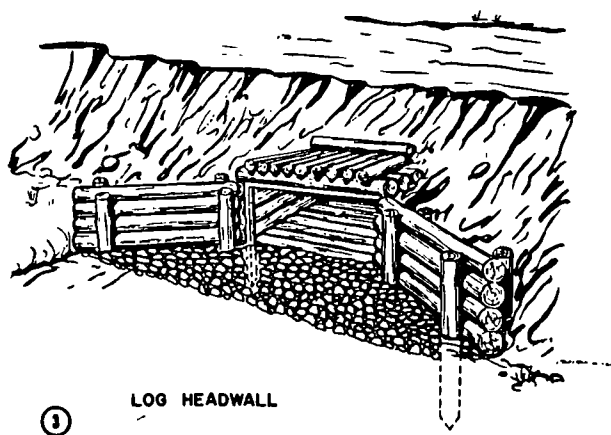
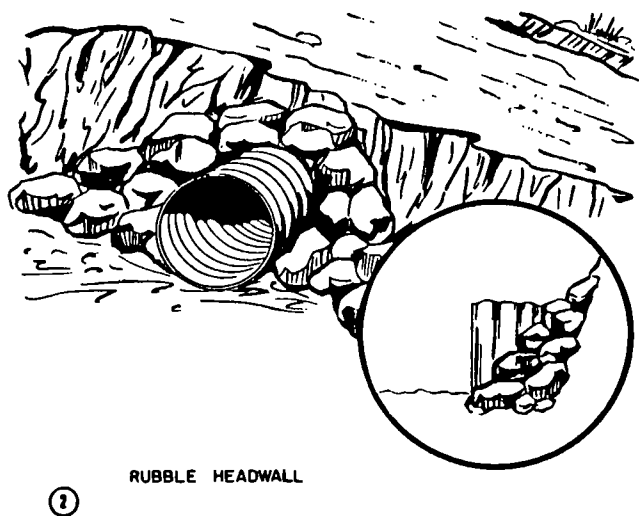


Figure 5-13—Continued.

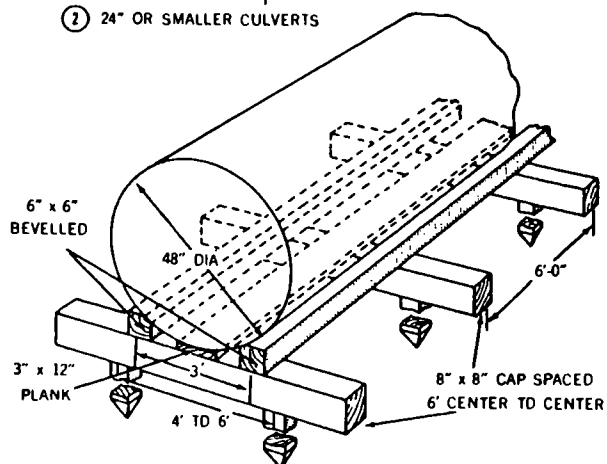
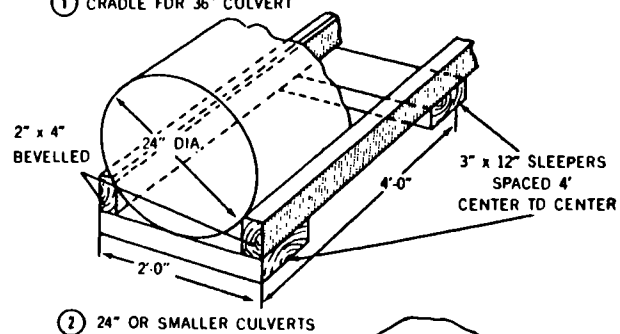
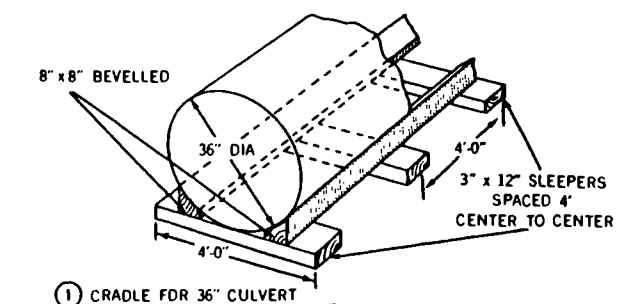


Figure 5-14. Foundation cradles for pipe culverts.

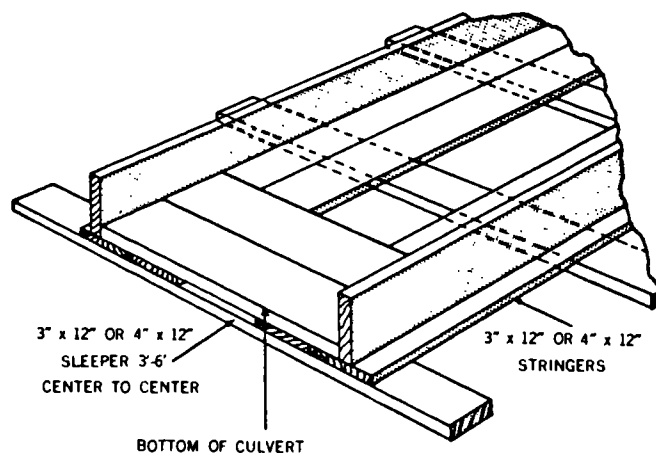


Figure 5-15. Spread footing for timber culverts.

Table 5-5. Minimum Pipe Cover Requirements for Airfields and Heliports

Feet of cover for

Pipe diameter in.	Standard strength clay and non-reinforced concrete pipe (ASTM C 13-57T and C 14-59, AASHO M 65-60 and M 86-60, and Fed Spec SS-P-361b (3))	Extra strength clay and non-reinforced concrete pipe (ASTM C 200-59T and C 14-59, AASHO M 65-60 and M 86-60, and Fed Spec SS-P-361b(3))	Asbestos-cement pipe (Fed Spec SS-P-331b)					Reinforced-concrete culverts and storm drains (ASTM C 76-62T and AASHO M 170-60)					Corrugated-steel pipe (Fed Spec WW-P-405)					
			Class 1500	Class 2400	Class 3300	Class 4000	Class 5000	Class I 1200 D	Class II 1500 D	Class III 2000 D	Class IV 3000 D	Class V 3750 D	18 Gage	16 Gage	14 Gage	12 Gage	10 Gage	8 Gage
			15,000-lb. Single-Wheel Load															
6	2.0	1.5	1.5	1.0	1.0								1.0	1.0				
12	2.5	2.0	2.5	2.0	1.5	1.0	1.0		2.5	2.0	1.5	1.0	1.0	1.0				
24	3.5	2.0		3.5	2.0	2.0	1.5		2.5	2.0	1.5	1.0		1.0	1.0	1.0	1.0	
36	2.5	2.0				2.5	2.0		2.5	2.0	1.5	1.0			1.0	1.0	1.0	1.0
48									2.5	2.0	1.5	1.0				1.0	1.0	1.0
60								2.5	2.0	2.0	1.5	1.0					1.0	1.0
72								2.5	2.0	2.0	1.5	1.0					1.5	1.5
84								2.5	2.0	2.0	1.5	1.0						1.5
96								2.5	2.0	2.0	1.5							1.5
108								2.5	2.0	2.0								
			25,000-lb. Single-Wheel Load															
6	2.5	1.5	2.0	1.5	1.0								1.0	1.0				
12	3.5	2.5	3.5	2.5	2.0	1.5	1.5		3.5	3.0	2.0	1.5	2.0	1.5	1.0			
24	4.5	2.5		4.5	3.0	2.5	2.0		3.5	2.5	2.0	1.5		2.0	1.5	1.5	1.0	
36	3.0	2.5				3.0	2.5		3.0	2.5	2.0	1.5			2.0	2.0	1.5	1.0
48									3.0	2.5	2.0	1.5				2.5	2.0	1.5
60								3.5	3.0	2.5	2.0	1.5					2.5	2.0
72								3.5	2.5	2.0	2.0	1.5					3.0	2.5
84								3.0	2.5	2.0	2.0							3.0
96								3.0	2.5	2.0								
108								3.0	2.5	2.0								
			100,000-lb Twin-Wheel Assembly Load															
6	8.0	3.5	5.0	3.0	2.5								2.5	2.0				
12	---	6.0	--	6.0	4.5	3.5	3.0		---	---	5.0	4.0	3.0	3.0	3.0			
24	---	6.5		---	---	7.5	5.5		---	7.5	4.5	3.5		5.0	4.0	3.5	3.0	
36	---	7.0				---	---		---	7.0	4.0	3.0			5.5	4.5	4.0	3.5
48									---	6.0	4.0	3.0				5.0	5.0	4.0
60								---	---	6.0	4.0	3.0					5.5	5.0
72								---	---	5.5	3.5	3.0					6.0	5.5
84								---	---	5.5	3.5							6.0
96								---	---	5.5								
108								---	---	5.0								
			265,000-lb. Twin-Twin Assembly Load															
6	---	6.0	8.0	5.0	3.5								3.5	3.0				
12	---	---	---	---	8.0	6.0	5.0		---	---	9.5	6.5	4.0	3.5	3.5			
24	---	---		---	---	---	---		---	---	8.0	6.0		7.0	6.0	4.5	4.0	
36	---	---			---	---	---		---	---	7.5	6.0			9.0	8.0	7.0	6.5

48										7.0	5.5				9.0	8.5	8.0
60								---	---	6.5	5.0					9.0	8.5
72								---	---	6.0	5.0					9.5	9.0
84								---	---	6.0							9.5

Notes.

1. Except where individual pipe installation designs are made, cover for pipe beneath runways, taxiways, aprons, or similar traffic areas will be provided in accordance with this table except as provided in note 7 for pipe underlying rigid pavements.

2. Cover for pipe in airfield nontraffic areas will be designed for 15,000-lb. single-wheel load.

3. Cover depths are measured from top of flexible pavement or unsurfaced areas to top of pipe.

4. Pipe produced by certain manufacturers exceeds strength requirements established by indicated standards. When additional strength is proved, the minimum cover may be reduced accordingly.

5. Dashes indicate allowable load is less than load on pipe; blanks indicate that pipe is not specified by the applicable standards. Largest size nonreinforced concrete pipe specified by applicable standards is 24-inch pipe.

6. "D" loads listed for the various classes of reinforced-concrete pipe are the minimum required 3-edge test loads to produce ultimate failure, in pounds per linear foot per foot of internal pipe diameter.

7. Pipe placed under airfield rigid pavements will have a minimum cover, measured from the bottom of the slab, as follows:

Pipe sizes, in.	Minimum cover, ft., for loads of			
	15,000-lb. single-wheel	25,000-lb. single-wheel	100,000-lb. twin assembly	265,000-lb. twin-twin assembly
6-60	0.5	0.5	1.0	1.0
66-108	1.0	1.0	1.5	1.5

8. The class designation number for asbestos-cement pipe is the minimum required 3-edge test load to produce ultimate failure in pounds per linear foot. It is independent of pipe diameter. An equivalent to the D load can be obtained by dividing the number in the class designation by the internal pipe diameter in feet.

**Table 5-6. Maximum Permissible Cover for Corrugated Steel Pipe
(Fill Areas Except Airfields)**

Diameter, in.	Permissible maximum cover above top of pipe, ft.									
	Circular section, gages and thicknesses					Vertically elongated section, gages and thicknesses				
	16 0.060	14 0.075	12 0.105	10 0.135	8 0.164	16 0.060	14 0.075	12 0.105	10 0.135	8 0.164
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
8	50									
10	35	40								
12	30	35	40							
15	25	30	35							
18	20	25	30							
21	20	25	30							
24	10	20	30	35						
30	---	20	25	30	35					
36	---	10	20	25	30					
42	---	---	15	20	30					
48	---	---	15	20	25	---	---	20	25	30
54	---	---	10	15	20	---	---	15	20	25
60	---	---	---	10	20	---	---	---	15	25
66	---	---	---	10	15	---	---	---	15	20
72	---	---	---	---	10	---	---	---	10	15
78	---	---	---	---	---	---	---	---	---	15
84	---	---	---	---	---	---	---	---	---	10

Notes.

1. Corrugated-aluminum-alloy pipe will conform to the requirements of AASHO Standard M196-62I.
2. Table will be used for normal installation conditions for loads ranging from dead (earth) load only to dead load plus H20-44 live load or dead load plus Cooper E-60 railway loading.
3. Vertical elongation will be accomplished by either shop fabrication or field strutting and will generally be 5 percent of the pipe diameter.

**Table 5-7. Maximum Permissible Cover for Corrugated Aluminum Alloy Pipe
(Fill Areas Except Airfields)**

Diameter, in.	Permissible maximum cover above top of pipe, ft.									
	Circular section					Vertically elongated section				
	Gage					Gage				
	16	14	12	10	8	16	14	12	10	8
8	80									
10	60	80								
12	60	70	80							
15	50	70	80							
18	40	60	80							
21	35	50	80							
24	15	45	70	80						
30	---	30	45	70	80					
36	---	15	30	45	70					
42	---	---	25	35	60					
48	---	---	20	25	35	---	---	25	70	80
54	---	---	15	20	30	---	---	20	50	80
60	---	---	---	15	25	---	---	---	45	80
66	---	---	---	15	20	---	---	---	35	70
72	---	---	---	10	15	---	---	---	25	60
78	---	---	---	---	---	---	---	---	---	25
84	---	---	---	---	---	---	---	---	---	20

Notes.

1. Except for gage tables, corrugated steel pipe will conform to the requirements of Federal Specification WW-P-405.
2. Table to be used for normal installation conditions for loads ranging from dead (earth) load only to dead load plus H20-44 live load or dead load plus Cooper E-60 railway loading.
3. Vertical elongation will be accomplished by either shop fabrication or field strutting and will generally be 5 percent of the pipe diameter.

CHAPTER 6

ROADS, RAILROADS, AND BRIDGES

Section I. MILITARY ROADS

6-1. Background

FM 5-36 covers route reconnaissance, road classification, and marking. TM 5-330 deals with reconnaissance, design, construction, maintenance, and repair of roads. The TM 5-331 series (A through E) deals with the use of construction equipment, and TM 5-337 covers bituminous and portland cement concrete paving. TM 5-349 deals with the special problems of road construction under Arctic weather conditions.

6-2. Nomenclature and Criteria

a. The specifications listed in tables 6-1, 6-2, and

6-3 will, under most conditions, give a combat road which will meet military requirements; conserve time, labor, equipment, materials, and transportation; and provide at least minimum driving safety. Those specifications related primarily to safety are not to be considered as "must" specifications, but rather specifications to be met whenever possible and without undue sacrifice of other considerations. Although they are not rigidly required, this does not mean that they are not important.

b. Figures 6-1 and 6-2 are a cross section and a perspective illustrating road nomenclature.

Table 6-1. Summary of Military Road Specifications

Characteristic	Specification
1 WIDTH:	
Traveled way (single lane)	Minimum—11½ feet.
Traveled way (two lanes)	Minimum—23 feet.
Shoulders (each side)	Minimum—4 feet.
Clearing	Minimum—6 feet on each side of roadway.
Widening on curves	See table 6-2.
2 ALINEMENT:	
Grades:	
Absolute maximum	Maximum grade vehicle can travel on.
Normal maximum	10 percent.
Desirable maximum	Tangents and gentle curves, less than 6 percent; sharp curves, less than 4 percent.
Horizontal curve radius	Minimum—150 feet.
Vertical curve length:	
Invert (Sag) curves	100 feet minimum for each 4 percent algebraic difference in grades.
Overt (Crest) curves	125 feet minimum for each 4 percent algebraic difference in grades.
Sight distance:	See table 6-3.
3 LOAD OPERATION CAPACITY:	
Road proper	Sustain design number of equivalent 18,000-lb operations/day.
Bridges	Accommodate using traffic.
4 SLOPES:	
Shoulders	¾ inch per foot.
Crown (gravel and dirt)	½ to ¾ inch per foot.
Crown (paved)	¼ to ½ inch per foot.
Superelevation (gravel and dirt)	½ to 1¼ inch per foot.
Superelevation (paved)	¼ to 1¼ inch per foot.
Cut	Variable.
Fill	Variable.

Table 6-1. Summary of Military Road Specifications

Characteristic	Specification
5 MISCELLANEOUS:	
Overhead clearance	Minimum—14 feet.
Traffic volume	2,000 vehicles per day, per lane at 25-35 mph.
Turnouts (single lane)	Minimum—every ¼ mile.

Table 6-2. Widening of Two-Way Road on Curves

Degree of curvature	Radius (feet)	Widening (feet)
4	1,432	2
5	1,146	2
6	955	2
7	819	2
8	716	2
9	637	2
10	573	2
11	521	2
12	477	3
14	409	3
16	358	3
18	318	3
20	286	3
22	260	3
24	239	4
25	229	4
30	191	4
35	164	5
40	143	5

Table 6-3. Minimum Passing and Stopping Sight Distance

Design speed (mph)	Passing sight distance (feet)		Stopping sight distance (feet)
	Desirable	Minimum	
30	600	500	200
40	1,100	900	275
50	1,600	1,400	350

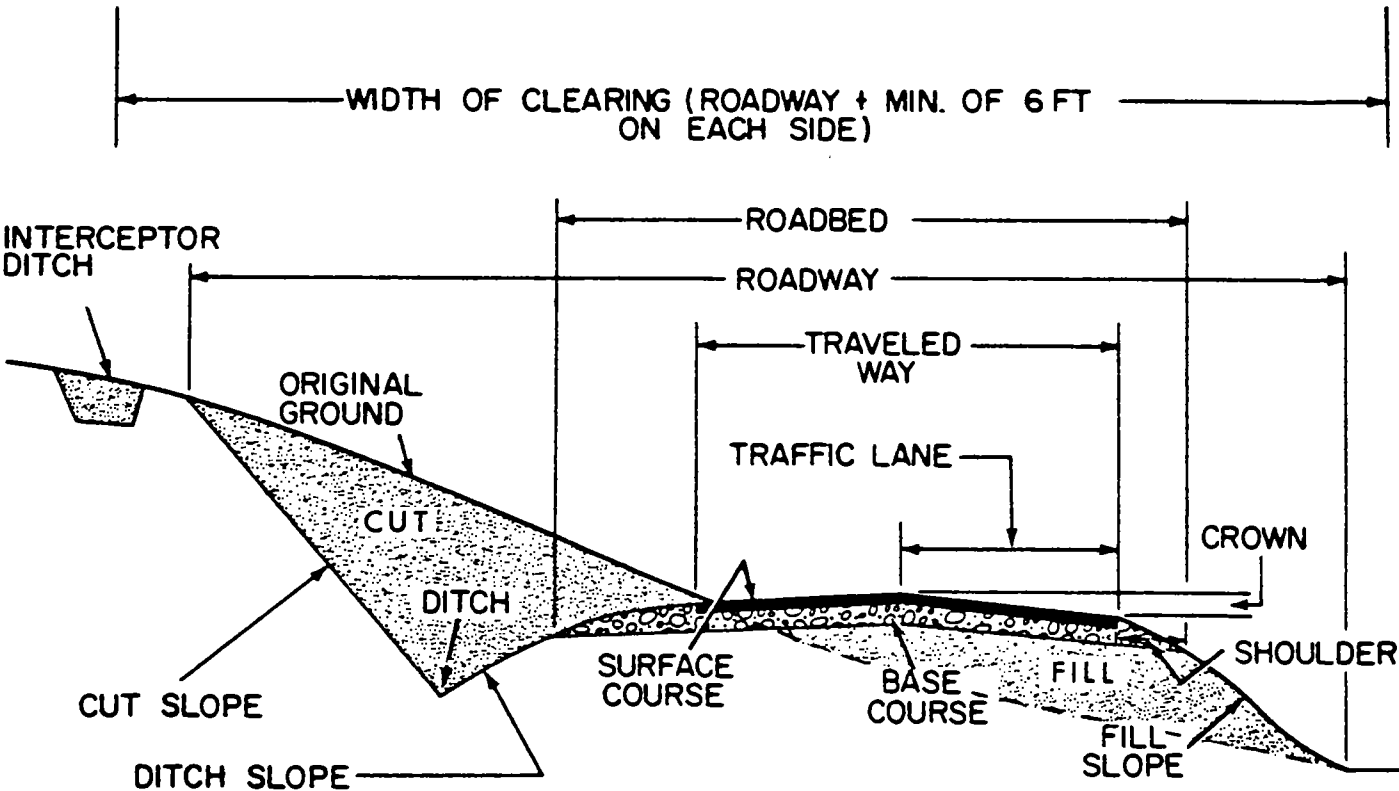


Figure 6-1. Typical cross section illustrating road nomenclature.

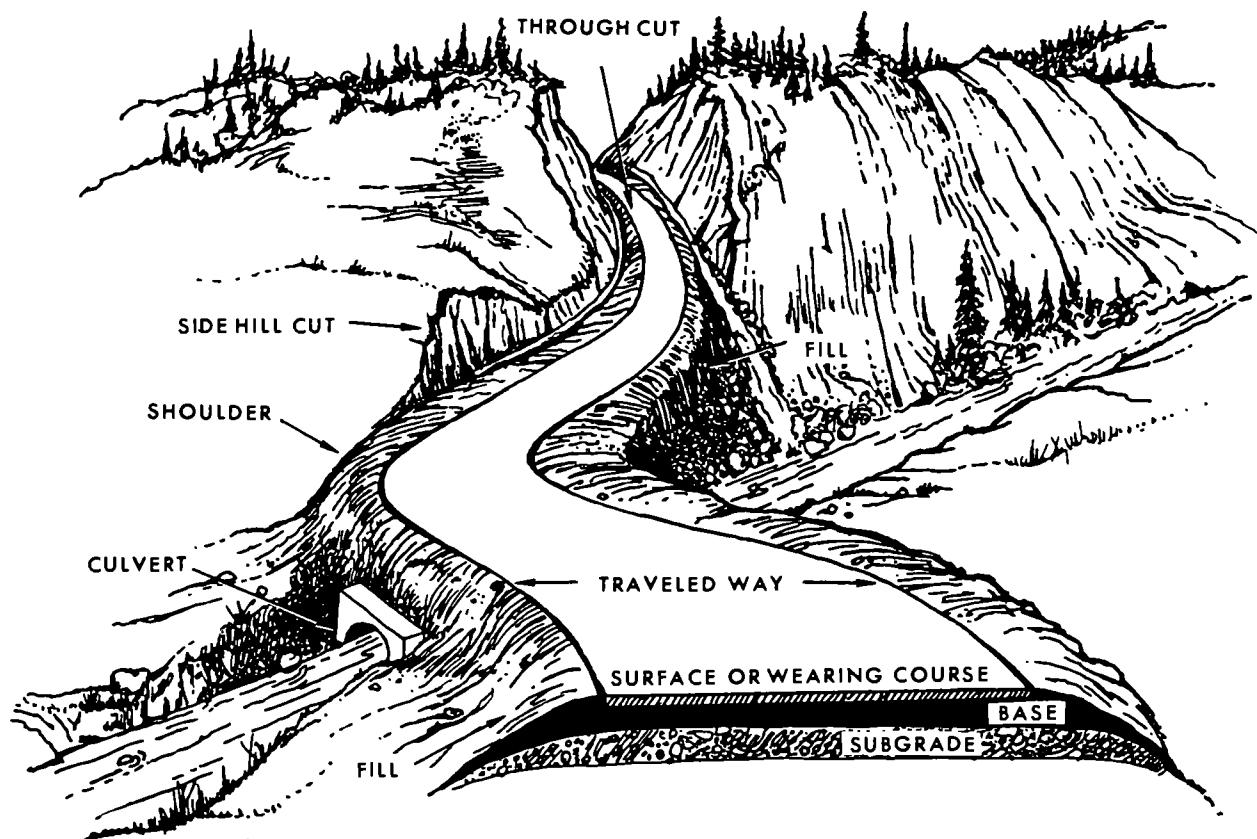


Figure 6-2. Perspective of road illustrating road nomenclature.

6-3. Design

a. Procedure. The design of a flexible pavement to be used as a *military road* in a theater of operations consists of:

(1) Estimating the number of operations each type of vehicle is expected to use the proposed road during its design life. This may be based on knowledge of traffic using similar use roads or on anticipated traffic. It must be borne in mind that the greatest influence on thickness design is the type and number of operations of very heavy vehicles. This will be made clear in the example problem given herein.

(2) Estimating how long a period of time the proposed road will be needed. This is called its "design life."

(3) Converting the operations of each type of vehicle into equivalent 18,000 lb, single-axle, dual-wheel load operations through the use of equivalent operation factors shown in figures 6-3 and 6-4.

(4) Summing up total number for equivalent 18,000 lb, single-axle, dual-wheel load operations from the design curves shown in figure 6-5.

b. Design Example. To illustrate thickness de-

sign by the CBR method, assume that an M.S.R. is to be designed for a 2 year design life on a subgrade with a design CBR value of 10. The road is to be an all-weather road and materials and equipment are available to construct an asphalt concrete surface. Ample quantity of base course material with a CBR value of 50 is available. In addition, a pit has been located adjacent to the road site that will furnish material for subbase with CBR value of 40. Assume further that as a result of study of previous M.S.R.'s, it is estimated that this road will be subjected to the following average daily volume of traffic:

Axle or gross load (lbs)	Single axle operations per day	Tandem axle operations per day	Tracked vehicle operations per day
1,000	500	---	---
1,500	400	---	---
3,000	300	---	---
4,000	100	---	---
5,000	---	20	---
10,000	50	100	25
20,000	20	200	---
30,000	---	50	---
32,000	---	---	15
80,000	---	---	10

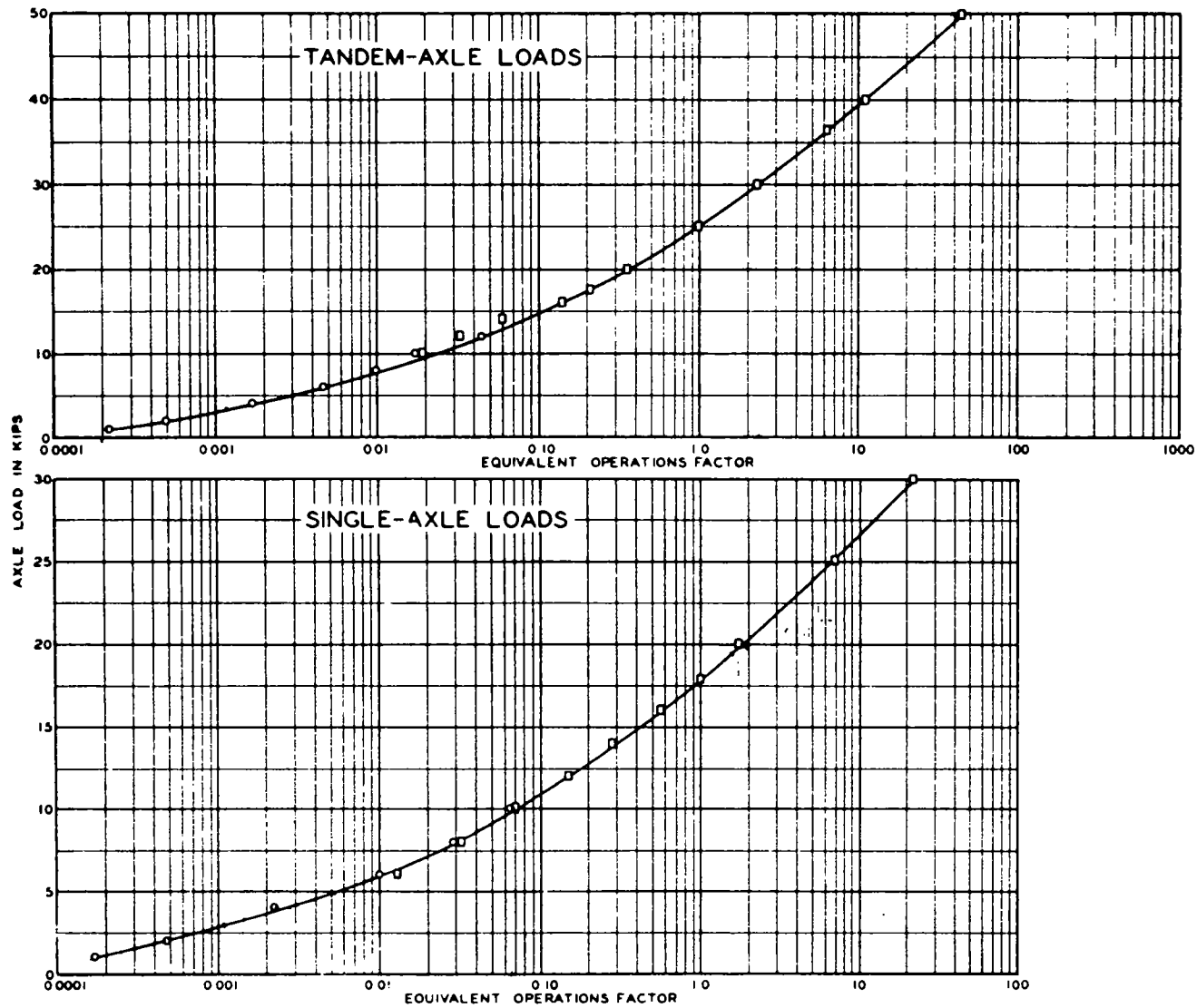


Figure 6-3. Equivalent operations factors for tandem-axle loads and single-axle loads.

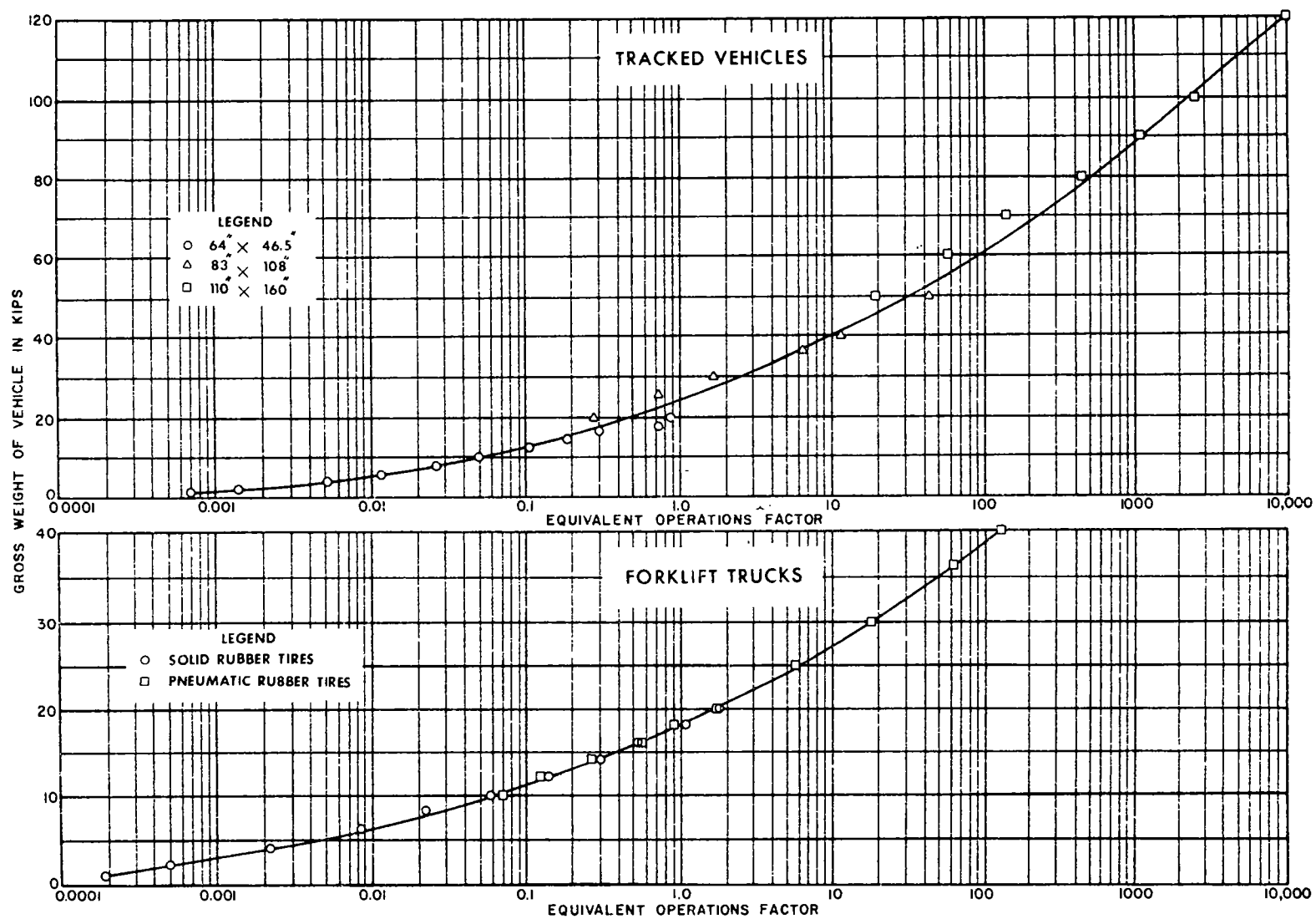


Figure 6-4. Equivalent operations factors for tracked vehicles and forklift trucks.

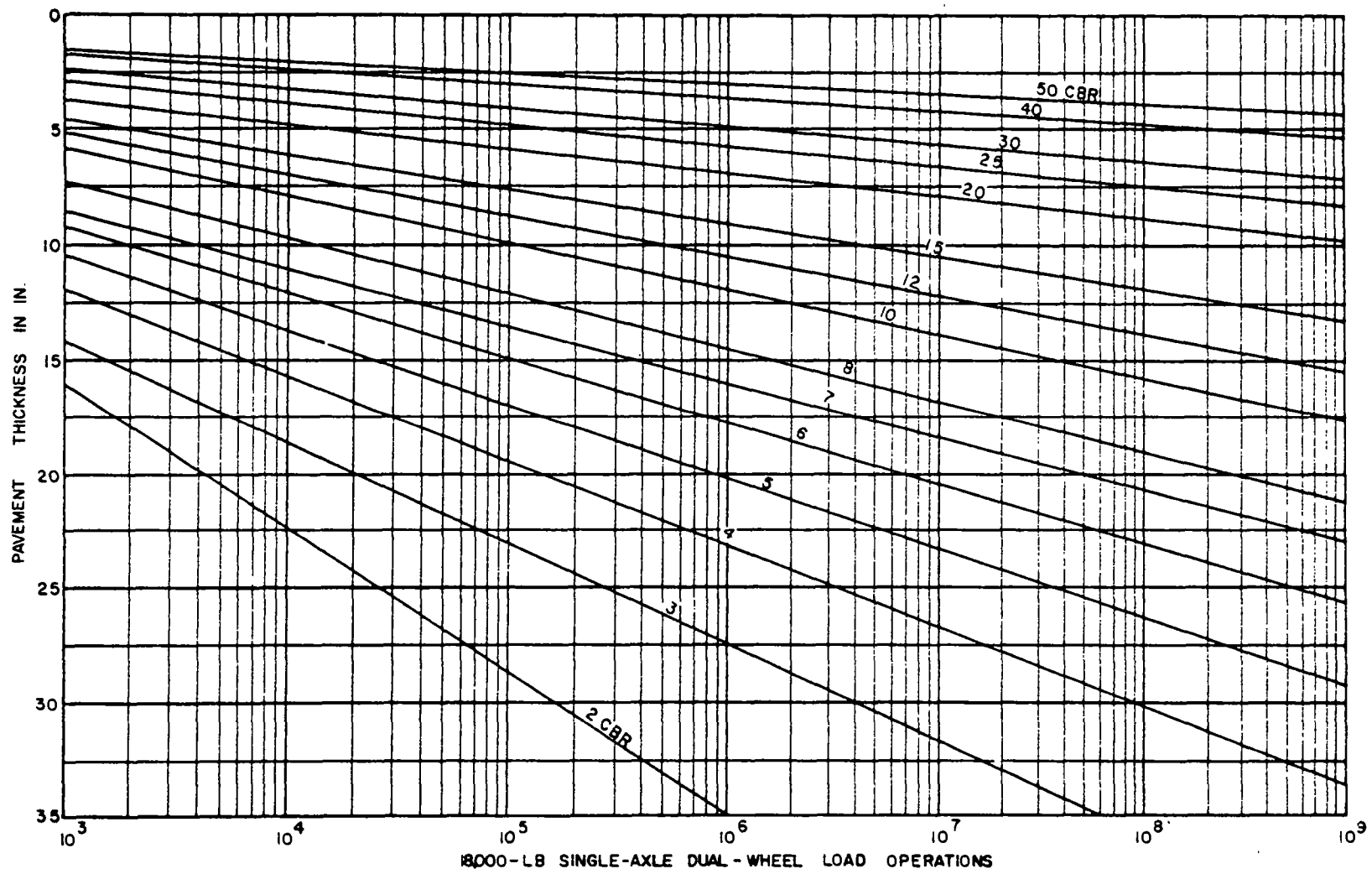


Figure 6-5. CBR design curves for 18,000 lb single-axle dual-wheel load, thickness vs operations.

Convert operations of these axle and gross loads into equivalent 18,000 lb, single-axle, dual-wheel load operations through use of the Equivalent Operations Factor Curves shown on figures 6-3 and 6-4 as follows:

Axle or gross Load (lb) *	Operation factor **	Operations per day	Equivalent operations per day
<i>Single axle</i>			
1,000	0.00016	× 500 =	0.08
1,500	0.0003	× 400 =	0.12
3,000	0.0012	× 300 =	0.36
4,000	0.0028	× 100 =	0.28
10,000	0.070	× 50 =	3.50
20,000	1.80	× 20 =	36.00
			40.34
<i>Tandem axle</i>			
5,000	0.0031	× 20 =	0.062
10,000	0.024	× 100 =	2.400
20,000	0.360	× 200 =	72.000
30,000	2.30	× 50 =	115.000
			189.462
<i>Tracked vehicles</i>			
10,000	0.05	× 25 =	1.25
32,000	2.70	× 15 =	40.50
80,000	480.00	× 10 =	4800.00
			4841.75
Total equivalent operations per day -----			5071.55

* Axle loads apply to wheeled vehicles.
Gross loads apply to tracked vehicles and forklift trucks.
** Values read from figures 6-3 and 6-4.
Equivalent operations in the 2 year life:
 $365 \text{ days} \times 2 \text{ years} \times 5071 \text{ total equivalent operations} = 3,701,830$
or 3.7×10^6 .

(It can be seen that the Equivalent Operations per day for the Single Axle vehicles could have been disregarded without affecting the result. Note, however, the tremendous value obtained from tracked vehicles.)

The first step is to determine the amount of cover required over the CBR 10 subgrade. Entering figure 6-5 at 3.7×10^6 of equivalent operations, going vertically up to CBR 10 value, thence horizontally to the left, it is found that the CBR 10 material must have a cover of 13".

Table 6-4 indicates that the minimum thickness of pavement and base course worth CBR value of 50 with an anticipated traffic of 3.7×10^6 equivalent operations is $3\frac{1}{2}$ " of pavement and 4" of base course which is in excess of cover requirement of 4" over the CBR 40 material. These values of thickness of base and pavement were determined as follows:

Since the equivalent operations of 3.7×10^6 (3,700,000) falls within the value of 7×10^5 (700,000) and 7×10^6 (7,000,000), line 5 of the above table is used, entering line 5 and proceeding horizontally to the right and reading under the column of 50 CBR Base, the values listed above are found. The sketch below indicates the proposed design for the flexible pavement structure.

13"	3½" A.C. Pavement
	4" CBR 50 Base Course Cohesionless
	5½" CBR 40 Subbase Cohesionless
	CBR 10 Subgrade Cohesive

The recommended compaction as outlined previously for the cohesionless base and subbase is 100 percent and for the top 6 inches of the cohesive subgrade is 90 percent of modified AASHTO maximum density. The most common type of bituminous wearing surface that can be expected to be constructed in the theater of operations is surface treatment. From experience on the use of surface treatment on base courses with CBR less than 80 it has been found that constant maintenance is a necessity. Assume now in the above example that pavement could not be placed due to lack of materials and equipment and surfacing would be limited to multiple surface treatment. The construction in this example problem is limit-

Table 6-4. Recommended Minimum Thickness of Pavement and Base

Line No.	Equivalent 18,000 lb single-axle, dual-wheel load operations	100 CBR base		80 CBR base		50 CBR base	
		Pvmt in	Base in	Pvmt in	Base in	Pvmt in	Base in
1	3×10^2 or less	ST ^a	4	MST ^b	4	1½	4
2	3×10^3 - 1.5×10^4	ST	4	MST	4	2	4
3	1.5×10^4 - 7×10^4	MST	4	1½	4	2½	4
4	7×10^4 - 7×10^5	MST	4	1½	4	3	4
5	7×10^5 - 7×10^6	1½	4	2	4	3½	4
6	7×10^6 - 7×10^7	1½	4	2½	4	4	4
7	7×10^7 - 7×10^8	2	4	3½	4	4½	4
8	7×10^8 - 7×10^9	3	4	3½	4	5	4

^a Single bituminous surface treatment

^b Multiple bituminous surface treatment

Table 6-5. Earthwork Table—Cubic Yards

3,000	2,900	2,800	2,700	2,600	2,500	2,400	2,300	2,200	2,100	2,000	1,900	1,800	1,700	1,600	1,500	1,400	1,300	1,200	1,100	1,000
1,520	1,555	1,512	1,458	1,404	1,350	1,295	1,242	1,188	1,134	1,080	1,025	972	918	854	810	756	702	548	594	540
1,521	1,557	1,513	1,459	1,405	1,351	1,297	1,243	1,189	1,135	1,081	1,027	973	919	855	811	757	703	549	595	541
1,522	1,558	1,514	1,460	1,406	1,352	1,298	1,244	1,190	1,136	1,082	1,028	974	920	856	812	758	704	550	596	542
1,523	1,559	1,515	1,461	1,407	1,353	1,299	1,245	1,191	1,137	1,083	1,029	975	921	857	813	759	705	551	597	543
1,524	1,570	1,515	1,462	1,408	1,354	1,300	1,245	1,192	1,138	1,084	1,030	975	922	858	814	750	705	552	598	544
1,525	1,571	1,517	1,453	1,409	1,355	1,301	1,247	1,193	1,139	1,085	1,031	977	923	859	815	751	707	553	599	545
1,525	1,572	1,518	1,454	1,410	1,355	1,302	1,248	1,194	1,140	1,085	1,032	978	924	870	815	752	708	554	500	545
1,527	1,573	1,519	1,455	1,411	1,357	1,303	1,249	1,195	1,141	1,087	1,033	979	925	871	817	753	709	555	601	547
1,528	1,574	1,520	1,465	1,412	1,358	1,304	1,250	1,195	1,142	1,088	1,034	980	926	872	818	754	710	555	502	548
1,529	1,575	1,521	1,467	1,413	1,359	1,305	1,251	1,197	1,143	1,089	1,035	981	927	873	819	755	711	557	503	549
1,530	1,575	1,522	1,468	1,414	1,360	1,305	1,252	1,198	1,144	1,090	1,035	982	928	874	820	755	712	558	604	550
1,531	1,577	1,523	1,469	1,415	1,361	1,307	1,253	1,199	1,145	1,091	1,037	983	929	875	821	757	713	559	605	551
1,532	1,578	1,524	1,470	1,415	1,362	1,308	1,254	1,200	1,146	1,092	1,038	984	930	876	822	758	714	560	606	552
1,533	1,579	1,525	1,471	1,417	1,363	1,309	1,255	1,201	1,147	1,093	1,039	985	931	877	823	759	715	561	607	553
1,534	1,580	1,525	1,472	1,418	1,364	1,310	1,255	1,202	1,148	1,094	1,040	985	932	878	824	770	715	552	508	554
1,535	1,581	1,527	1,473	1,419	1,355	1,311	1,257	1,203	1,149	1,095	1,041	987	933	879	825	771	717	553	609	555
1,536	1,582	1,528	1,474	1,420	1,366	1,312	1,258	1,204	1,150	1,096	1,042	988	934	880	826	772	718	554	510	555
1,537	1,583	1,529	1,475	1,421	1,367	1,313	1,259	1,205	1,151	1,097	1,043	989	935	881	827	773	719	555	511	557
1,538	1,584	1,530	1,476	1,422	1,368	1,314	1,260	1,206	1,152	1,098	1,044	990	936	882	828	774	720	556	512	558
1,539	1,585	1,531	1,477	1,423	1,369	1,315	1,261	1,207	1,153	1,099	1,045	991	937	883	829	775	721	557	513	559
1,540	1,585	1,532	1,478	1,424	1,370	1,316	1,262	1,208	1,154	1,100	1,046	992	938	884	830	776	722	558	514	560
1,541	1,587	1,533	1,479	1,425	1,371	1,317	1,263	1,209	1,155	1,101	1,047	993	939	885	831	777	723	559	515	551
1,542	1,588	1,534	1,480	1,425	1,372	1,318	1,264	1,210	1,156	1,102	1,048	994	940	886	832	778	724	560	516	552
1,543	1,589	1,535	1,481	1,427	1,373	1,319	1,265	1,211	1,157	1,103	1,049	995	941	887	833	779	725	561	517	553
1,544	1,590	1,535	1,482	1,428	1,374	1,320	1,265	1,212	1,158	1,104	1,050	995	942	888	834	780	726	562	518	554
1,545	1,591	1,537	1,483	1,429	1,375	1,321	1,267	1,213	1,159	1,105	1,051	997	943	889	835	781	727	563	519	555
1,545	1,592	1,538	1,484	1,430	1,376	1,322	1,268	1,214	1,160	1,106	1,052	998	944	890	835	782	728	564	520	555
1,547	1,593	1,539	1,485	1,431	1,377	1,323	1,269	1,215	1,161	1,107	1,053	999	945	891	837	783	729	565	521	557
1,548	1,594	1,540	1,485	1,432	1,378	1,324	1,270	1,216	1,162	1,108	1,054	1,000	946	892	838	784	730	566	522	558
1,549	1,595	1,541	1,487	1,433	1,379	1,325	1,271	1,217	1,163	1,109	1,055	1,001	947	893	839	785	731	567	523	559
1,550	1,596	1,542	1,488	1,434	1,380	1,326	1,272	1,218	1,164	1,110	1,056	1,002	948	894	840	786	732	568	524	570
1,551	1,597	1,543	1,489	1,435	1,381	1,327	1,273	1,219	1,165	1,111	1,057	1,003	949	895	841	787	733	569	525	571
1,552	1,598	1,544	1,490	1,436	1,382	1,328	1,274	1,220	1,166	1,112	1,058	1,004	950	896	842	788	734	570	526	572
1,553	1,599	1,545	1,491	1,437	1,383	1,329	1,275	1,221	1,167	1,113	1,059	1,005	951	897	843	789	735	571	527	573
1,554	1,600	1,546	1,492	1,438	1,384	1,330	1,276	1,222	1,168	1,114	1,060	1,005	952	898	844	790	735	572	528	574
1,555	1,601	1,547	1,493	1,439	1,385	1,331	1,277	1,223	1,169	1,115	1,061	1,007	953	899	845	791	737	573	529	575
1,556	1,602	1,548	1,494	1,440	1,385	1,332	1,278	1,224	1,170	1,115	1,062	1,008	954	900	846	792	738	574	530	576
1,557	1,603	1,549	1,495	1,441	1,387	1,333	1,279	1,225	1,171	1,117	1,063	1,009	955	901	847	793	739	575	531	577
1,558	1,604	1,550	1,495	1,442	1,388	1,334	1,280	1,226	1,172	1,118	1,064	1,010	955	902	848	794	740	576	532	578
1,559	1,605	1,551	1,497	1,443	1,389	1,335	1,281	1,227	1,173	1,119	1,065	1,011	957	903	849	795	741	577	533	579
1,560	1,605	1,552	1,498	1,444	1,390	1,335	1,282	1,228	1,174	1,120	1,065	1,012	958	904	850	796	742	578	534	580
1,561	1,607	1,553	1,499	1,445	1,391	1,337	1,283	1,229	1,175	1,121	1,067	1,013	959	905	851	797	743	579	535	581
1,562	1,608	1,554	1,500	1,445	1,392	1,338	1,284	1,230	1,175	1,122	1,068	1,014	960	906	852	798	744	580	535	582
1,563	1,609	1,555	1,501	1,447	1,393	1,339	1,285	1,231	1,177	1,123	1,069	1,015	961	907	853	799	745	581	537	583
1,564	1,610	1,556	1,502	1,448	1,394	1,340	1,285	1,232	1,178	1,124	1,070	1,015	962	908	854	800	745	582	538	584
1,565	1,611	1,557	1,503	1,449	1,395	1,341	1,287	1,233	1,179	1,125	1,071	1,017	963	909	855	801	747	583	539	585
1,566	1,612	1,558	1,504	1,450	1,395	1,342	1,288	1,234	1,180	1,125	1,072	1,018	964	910	856	802	748	584	540	585
1,567	1,613	1,559	1,505	1,451	1,397	1,343	1,289	1,235	1,181	1,127	1,073	1,019	965	911	857	803	749	585	541	587
1,568	1,614	1,560	1,506	1,452	1,398	1,344	1,290	1,236	1,182	1,128	1,074	1,020	965	912	858	804	750	586	542	588
1,569	1,615	1,561	1,507	1,453	1,399	1,345	1,291	1,237	1,183	1,129	1,075	1,021	967	913	859	805	751	587	543	589
1,570	1,615	1,562	1,508	1,454	1,400	1,345	1,292	1,238	1,184	1,130	1,076	1,022	968	914	860	805	752	588	544	590
1,571	1,617	1,563	1,509	1,455	1,401	1,347	1,293	1,239	1,185	1,131	1,077	1,023	969	915	861	807	753	589	545	591
1,572	1,618	1,564	1,510	1,456	1,402	1,348	1,294	1,240	1,186	1,132	1,078	1,024	970	915	862	808	754	590	546	592
1,573	1,619	1,565	1,511	1,457	1,403	1,349	1,295	1,241	1,187	1,133	1,079	1,025	971	917	863	809	755	591	547	593

for Sum of End Areas—100 Foot Prisms

900	800	700	600	500	400	300	200	100	0	0.0	0.1	0.2	0.3	0.4	0.6	0.6	0.7	0.8	0.9
486	432	378	324	270	216	162	108	54	0	0.00	0.18	0.37	0.56	0.74	0.93	1.11	1.30	1.48	1.67
487	433	379	325	271	217	163	109	55	1	1.86	2.04	2.22	2.41	2.59	2.78	2.96	3.15	3.33	3.52
488	434	380	326	272	218	164	110	56	2	3.70	3.89	4.07	4.26	4.44	4.63	4.82	5.00	5.18	5.37
489	435	381	327	273	219	165	111	57	3	5.56	5.74	5.93	6.11	6.30	6.48	6.67	6.85	7.04	7.22
490	436	382	328	274	220	166	112	58	4	7.41	7.59	7.78	7.96	8.15	8.33	8.52	8.70	8.89	9.07
491	437	383	329	275	221	167	113	59	5	9.26	9.44	9.63	9.81	10.00	10.19	10.37	10.56	10.74	10.93
492	438	384	330	276	222	168	114	60	6	11.11	11.30	11.48	11.67	11.85	12.04	12.22	12.41	12.59	12.78
493	439	385	331	277	223	169	115	61	7	12.96	13.15	13.33	13.52	13.70	13.89	14.07	14.26	14.44	14.63
494	440	386	332	278	224	170	116	62	8	14.82	15.00	15.19	15.37	15.56	15.74	15.93	16.11	16.30	16.48
495	441	387	333	279	225	171	117	63	9	16.67	16.85	17.04	17.22	17.41	17.59	17.78	17.96	18.15	18.33
496	442	388	334	280	226	172	118	64	10	18.52	18.70	18.89	19.07	19.26	19.44	19.63	19.82	20.00	20.18
497	443	389	335	281	227	173	119	65	11	20.37	20.56	20.74	20.93	21.11	21.30	21.48	21.67	21.85	22.04
498	444	390	336	282	228	174	120	66	12	22.22	22.41	22.59	22.78	22.96	23.15	23.33	23.52	23.70	23.89
499	445	391	337	283	229	175	121	67	13	24.07	24.26	24.44	24.63	24.82	25.00	25.18	25.37	25.56	25.74
500	446	392	338	284	230	176	122	68	14	25.93	26.11	26.30	26.48	26.67	26.85	27.04	27.22	27.41	27.59
501	447	393	339	285	231	177	123	69	15	27.78	27.96	28.15	28.33	28.52	28.70	28.89	29.07	29.26	29.44
502	448	394	340	286	232	178	124	70	16	29.63	29.82	30.00	30.18	30.37	30.56	30.74	30.93	31.11	31.30
503	449	395	341	287	233	179	125	71	17	31.48	31.67	31.85	32.04	32.22	32.41	32.59	32.78	32.96	33.15
504	450	396	342	288	234	180	126	72	18	33.33	33.52	33.70	33.89	34.07	34.26	34.44	34.63	34.82	35.00
505	451	397	343	289	235	181	127	73	19	35.18	35.37	35.56	35.74	35.93	36.11	36.30	36.48	36.67	36.85
506	452	398	344	290	236	182	128	74	20	37.04	37.22	37.41	37.59	37.78	37.96	38.15	38.33	38.52	38.70
507	453	399	345	291	237	183	129	75	21	38.89	39.07	39.26	39.44	39.63	39.82	40.00	40.19	40.37	40.56
508	454	400	346	292	238	184	130	76	22	40.74	40.93	41.11	41.30	41.48	41.67	41.85	42.04	42.22	42.41
509	455	401	347	293	239	185	131	77	23	42.59	42.78	42.96	43.15	43.33	43.52	43.70	43.89	44.07	44.26
510	456	402	348	294	240	186	132	78	24	44.44	44.63	44.81	45.00	45.19	45.37	45.56	45.74	45.93	46.11
511	457	403	349	295	241	187	133	79	25	46.30	46.48	46.67	46.85	47.04	47.22	47.41	47.59	47.78	47.96
512	458	404	350	296	242	188	134	80	26	48.15	48.33	48.52	48.70	48.89	49.07	49.26	49.44	49.63	49.82
513	459	405	351	297	243	189	135	81	27	50.00	50.19	50.37	50.56	50.74	50.93	51.11	51.30	51.48	51.67
514	460	406	352	298	244	190	136	82	28	51.85	52.04	52.22	52.41	52.59	52.78	52.96	53.15	53.33	53.52
515	461	407	353	299	245	191	137	83	29	53.70	53.89	54.07	54.26	54.44	54.63	54.81	55.00	55.18	55.37
516	462	408	354	300	246	192	138	84	30	55.56	55.74	55.93	56.11	56.30	56.48	56.67	56.85	57.04	57.22
517	463	409	355	301	247	193	139	85	31	57.41	57.59	57.78	57.96	58.15	58.33	58.52	58.70	58.89	59.07
518	464	410	356	302	248	194	140	86	32	59.26	59.44	59.63	59.82	60.00	60.18	60.37	60.56	60.74	60.93
519	465	411	357	303	249	195	141	87	33	61.11	61.30	61.48	61.67	61.85	62.04	62.22	62.41	62.59	62.78
520	466	412	358	304	250	196	142	88	34	62.96	63.15	63.33	63.52	63.70	63.89	64.07	64.26	64.44	64.63
521	467	413	359	305	251	197	143	89	35	64.82	65.00	65.18	65.37	65.56	65.74	65.93	66.11	66.30	66.48
522	468	414	360	306	252	198	144	90	36	66.67	66.85	67.04	67.22	67.41	67.59	67.78	67.96	68.15	68.33
523	469	415	361	307	253	199	145	91	37	68.52	68.70	68.89	69.07	69.26	69.44	69.63	69.82	70.00	70.18
524	470	416	362	308	254	200	146	92	38	70.37	70.56	70.74	70.93	71.11	71.30	71.48	71.67	71.85	72.04
525	471	417	363	309	255	201	147	93	39	72.22	72.41	72.59	72.78	72.96	73.15	73.33	73.52	73.70	73.89
526	472	418	364	310	256	202	148	94	40	74.07	74.26	74.44	74.63	74.82	75.00	75.18	75.37	75.56	75.74
527	473	419	365	311	257	203	149	95	41	75.93	76.11	76.30	76.48	76.67	76.85	77.04	77.22	77.41	77.59
528	474	420	366	312	258	204	150	96	42	77.78	77.96	78.15	78.33	78.52	78.70	78.89	79.07	79.25	79.44
529	475	421	367	313	259	205	151	97	43	79.63	79.82	80.00	80.18	80.37	80.56	80.74	80.93	81.11	81.30
530	476	422	368	314	260	206	152	98	44	81.48	81.67	81.85	82.04	82.22	82.41	82.59	82.78	82.96	83.15
531	477	423	369	315	261	207	153	99	45	83.33	83.52	83.70	83.89	84.07	84.26	84.44	84.63	84.82	85.00
532	478	424	370	316	262	208	154	100	46	85.19	85.37	85.56	85.74	85.93	86.11	86.30	86.48	86.67	86.85
533	479	425	371	317	263	209	155	101	47	87.04	87.22	87.41	87.59	87.78	87.96	88.15	88.33	88.52	90.56
534	480	426	372	318	264	210	156	101	48	88.89	89.07	89.26	89.44	89.63	89.82	90.00	90.18	90.37	92.41
535	481	427	373	319	265	211	157	103	49	90.74	90.93	91.11	91.30	91.48	91.67	91.85	92.04	92.22	90.56
536	482	428	374	320	266	212	158	104	50	92.59	92.78	92.96	93.15	93.33	93.52	93.70	93.89	94.07	94.26
537	483	429	375	321	267	213	159	105	51	94.44	94.63	94.82	95.00	95.18	95.37	95.56	95.74	95.93	96.11
538	484	430	376	322	268	214	160	106	52	96.30	96.48	96.67	96.85	97.04	97.22	97.41	97.59	97.78	97.96
539	485	431	377	323	269	215	161	107	53	98.15	98.33	98.52	98.70	98.89	99.07	99.26	99.44	99.63	99.82

ed to the use of materials of CBR 40 subbase and CBR 50 base course. When figure 6-5 was used in above example it was found that a minimum of $3\frac{1}{2}$ " of pavement was required over the 50 CBR material. However, neither pavement material or material better than CBR 50 is available so it is necessary to use the CBR 50 to fill this gap, and accept the fact that heavy maintenance will be required.

The design for use of multiple surface treatment is as shown below:

Multiple Surface Treatment	
13"	7½" CBR 50 Base Course
	5½" CBR 40 Subbase Course
	CBR 10 Subgrade

The compacton should be the same as recommended for the thickness design example where pavement was used.

6-4. Earthwork

Volumes of earth to be moved are computed in order to facilitate the scheduling of equipment and the balancing of cut and fill. This generally is done by using the average end area formula or the average cut or fill table.

a. The average end area formula is—

$$V = (A_1 + A_2) \frac{L}{54}$$

where,

V = volume, cu yd

A_1 and A_2 = end areas, sq ft

L = distance between end areas, ft

The application of this formula becomes time consuming when many calculations are to be made. Table 6-5 has been developed to save time. It is used as follows:

(1) Obtain the sum of the end areas to one decimal place.

(2) Locate the whole number of this sum in the left portion of the table.

(3) Read the first portion of the volume at the top of column in which the whole number appears.

(4) Read right horizontally from the whole number and obtain the figure under the appropriate decimal. (If no decimal appears, 0.0 is assumed).

(5) Add the values of steps (3) and (4) to obtain the total volume in cubic yards for 100 ft of length between cross sections.

Example:

Given: $A_1 = 100$ sq ft

$A_2 = 128$ sq ft

$L = 81$ linear feet

Find: Volume by use of the table

Solution: $A_1 + A_2 = 100 + 128 = 228.0$ sq ft

From table for 228 = 400

for 0.0 = 22.22

422.22 for

100 ft

length

$$\text{Volume } 422.22 \times \frac{81}{100} = 342 \text{ cu yd.}$$

b. Having only the centerline profile plotted and the grade established, earthwork can be estimated from table 6-6. It is used as follows:

(1) Enter column 1 and read down to the average amount of cut or fill for the length concerned.

(2) Read horizontally to the right and obtain the figure under the appropriate base of cut or top of fill in columns 2 through 9.

(3) Make corrections to this figure from columns 10, 11, or 12 if they apply.

(4) If the length is not 100 feet between the points considered, adjust the answer proportionately.

c. Other methods for computing earthwork volumes are covered in TM 5-330.

d. Table 16-19 gives the normal conversion for earth-volume changes.

6-5. Maintenance

a. Ditches and culverts must be checked periodically for condition and to insure that debris has not accumulated to restrict or prevent free flow of water. Maintenance and repairs required on various types of road surfaces are shown in table 6-7.

b. Engineer units instruct and assist the using forces in the use of truck-drawn steel-edged timber drags for maintenance of interior roads in depots, bivouac areas, hospitals, and similar areas.

Table 6-6. Volume of Cuts and Fills in Cubic Yards per 100 Feet of Length (for Level Sections)

1	2	3	4	5	6	7	8	9	10	11	12
Average depth of cut height of fill (feet)	Side slope 1 to 1—width of base of cut or crown of fill (feet) ¹								Add for each additional 2 feet of width	Add where slope is 1½ to 1	Add where slope is 2 to 1
	14	16	18	20	24	28	30	42			
1.....	56	63	70	78	92	107	115	159	7	2	4
2.....	119	133	148	163	192	222	237	326	15	7	15
3.....	189	211	233	256	300	344	367	500	22	16	33
4.....	267	296	326	356	415	474	504	682	30	30	59
5.....	352	389	426	463	537	611	648	870	37	46	93
6.....	444	489	533	578	667	756	800	1,065	45	67	133
7.....	544	596	648	700	803	907	959	1,271	52	91	181
8.....	652	711	770	830	948	1,067	1,126	1,483	59	118	237
9.....	767	833	900	967	1,100	1,233	1,300	1,700	67	150	300
10.....	889	936	1,037	1,111	1,259	1,407	1,481	1,928	74	185	370
11.....	1,019	1,100	1,181	1,263	1,426	1,589	1,670	2,159	82	224	448
12.....	1,156	1,244	1,333	1,422	1,600	1,778	1,867	2,400	89	267	534
13.....	1,300	1,396	1,493	1,589	1,781	1,974	2,070	2,649	96	313	626
14.....	1,452	1,556	1,659	1,763	1,970	2,178	2,281	2,904	104	363	725
15.....	1,611	1,722	1,833	1,944	2,166	2,389	2,500	3,167	111	426	852
16.....	1,778	1,896	2,015	2,133	2,370	2,607	2,726	3,437	119	474	948
17.....	1,952	2,078	2,204	2,330	2,581	2,833	2,959	3,715	126	534	1,068
18.....	2,133	2,267	2,400	2,533	2,800	3,067	3,200	4,000	133	598	1,196
19.....	2,322	2,463	2,604	2,744	3,025	3,307	3,448	4,293	141	667	1,334
20.....	2,519	2,667	2,815	2,963	3,259	3,556	3,704	4,593	148	740	1,480
21.....	2,722	2,878	3,033	3,189	3,500	3,811	3,967	4,900	156	815	1,630
22.....	2,933	3,096	3,259	3,422	3,748	4,074	4,237	5,215	163	894	1,788

¹ Width of roadbed on fills should be for 2 feet greater than in cuts.

Table 6-7. Road Maintenance and Repair

Type of surface	Maintenance	Repair
Portland-cement concrete, asphaltic concrete, brick, stone, or wood block.	Clean dust and dirt from joints and cracks and refill with hot asphalt, tar, or a cement grout.	Repair by patching with bituminous premix, or with original material.
Bituminous surfaces	Occasional renewal of wearing surface by adding seal coat with mineral-aggregate cover.	Soft spots and breaks: Remove surface; correct drainage, base and/or subgrade; trim and square area to be patched; replace surface with bituminous premix. Ruts, waves, and shoves: Usually caused by excess bituminous material, improper curing or defective drainage. The latter may require complete removal of pavement. If pavement is roadmix type, scarify and disk material until broken up, blade from side to side of strip. If necessary add aggregate, reshape and roll. Apply seal coat if needed. In surface treatments; usually indicates bond between bituminous treatment and base course broken. Remove wearing course, recondition and reprime base, apply new surface treatment. Use surface material similar to original. Worn and raveled surface: In mixed material, remove surface full depth over defective area, cut square or rectangular opening with vertical edges. Clean base and apply tack coat, place mix and tamp, roll and check surface. In penetration-macadam or similar surface, repair by surface treating affected area with material similar to original pavement.

Table 6-7. Road Maintenance and Repair—Continued.

Type of surface	Maintenance	Repair
Untreated surfaces of gravel, crushed rock, sand-clay, etc. (includes surfaces treated with dust palliatives).	Reshape periodically, preferably while damp, using blade grader or road drag. If surface develops corrugations it should be scarified and reshaped. Periodically add additional surfacing to replace that worn and washed away. Dust palliatives may be applied periodically as needed during dry season.	Soft spots: Remove surface; correct base, subgrade or drainage difficulty; trim and square area; replace and compact surfacing. Repair of soft spot may sometimes be made by adding new layer of surfacing, keeping it maintained while it is being compacted by traffic.
Earth	Reshape periodically, preferably while damp, using blade grader or road drag. Dust palliatives may be applied periodically as needed during dry season.	Soft spots: Correct drainage and cover or mix with granular material to stabilize.
Corduroy	Maintain cover of brush and earth. Respike logs.	Reconstruct sections as required.
Plank	Replace broken timbers. Keep well spiked.	Reconstruct sections as required.

Section II. RAILROADS

6-6. References

Responsibilities regarding railroads are covered in AR 55-650. Details of railroad construction are covered in TM 5-370, and operation of railroads is covered in FM 55-15.

6-7. New Construction

a. For planning purposes, a railroad division includes 100 principal-route miles of main line, single or double track, with its terminal operating and maintenance facilities, fueling and watering facilities, and the signaling equipment or interlocking facilities necessary for safe operation. Passing sidings on single-track lines, cross-overs on double-track lines, and stations are located at intervals as required by traffic. Normally, at least one spur or siding is provided at each station. The Corps of Engineers is responsible for new rail construction and large-scale rehabilitation. Transportation personnel, however, may be required to assist Engineer personnel in the latter work.

b. Table 6-8 shows the material and net effective manhours required for new construction of 1 mile of standard-gage (56½-inch), single-track railroad.

c. Tie lengths and embankment widths for single-track lines of various gages are shown in figure 6-6. Embankment widths and other elements of double-track lines, standard gage, are shown in figure 6-7. The 13-foot track spacing, center to center, is satisfactory for tangent track

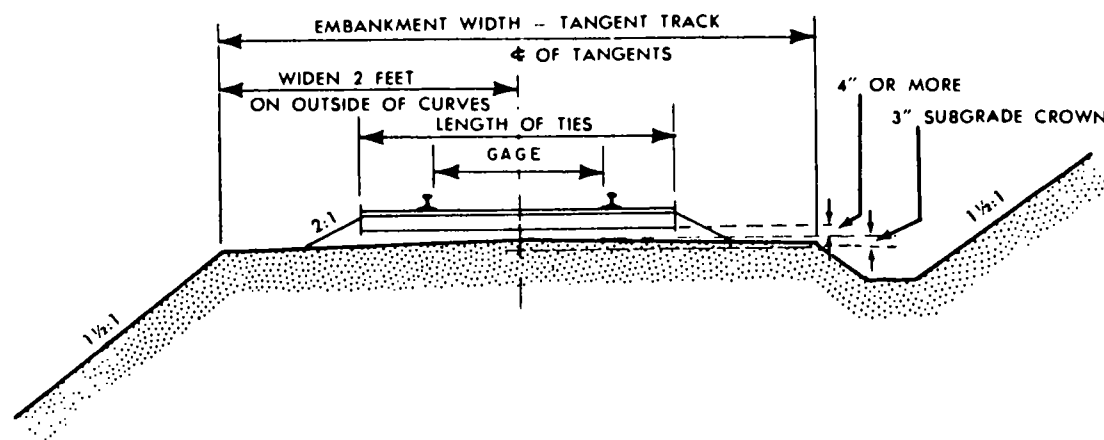
and is normally the minimum spacing used in multitrack layouts for both yard and running tracks. In curved track, it is satisfactory for slow traffic only, and the spacing is normally increased to 14 feet or more in running tracks to allow for overhang of equipment, rocking of cars, and inequalities of superelevation.

d. Body tracks in yards normally are spaced a minimum of 13 feet on centers, except that the first body track is 15 feet on centers from a running track; and ladder tracks are at least 15 feet on centers from any parallel track. Tracks in pairs for operation of locomotive cranes are spaced at least 18 feet on centers.

e. A general description of materials required for construction of standard-gage track is as follows:

(1) *Rail.* Rails are designated in the U.S. and other English-speaking countries by their weight per yard. In countries using the metric system the designation is in kilograms per meter. Weights vary greatly with gage and design, but normally are 85 pounds or higher for standard gage track. Usual rail length is 33 or 39 feet.

(2) *Ties.* Crossties are normally made of wood, are 6 to 7 inches thick, 8 to 10 inches wide, and the preferred length for a standard gage railroad is 8 feet 6 inches. Figure 6-6 gives lengths for other gages. Standard spacing is 19 and 21 ties per 39-foot rail for yard and running tracks, respectively. Switch ties come in sets, and



GAGE FT. INS.	LENGTH OF TIES FT. INS.	EMBANKMENT WIDTH TANGENT TRACK FT. INS.
2'-6" OR LESS	7'-0"	15'-0"
3'-0"		
3'-3"		
3'-3 1/2" (METER)		
3'-5 1/2"	7'-6"	15'-0"
3'-6"		
4'-8 1/2" (STANDARD)	8'-6" TO 9'-0"	16'-0"
5'-0"		
5'-3"		
5'-6"		
	9'-6" TO 10'-0"	18'-0"

Figure 6-6. Cross section, single track.

bridge ties vary in length depending upon type of bridge. Details are covered in TM 5-370.

(3) *Tie plates, spikes, and bolts.* Steel tie plates, 9 by 6 by $\frac{3}{8}$ inches in size, are authorized for all track but may be omitted in hasty construction except at turnouts and sharp curves. Spikes are issued in the 9/16- by $5\frac{1}{2}$ -inch size, and track bolts in $\frac{7}{8}$ - by $4\frac{1}{2}$ -inch sizes.

(4) *Ballast.* Crushed rock, slag, or gravel, in sizes graded from 3-inch to number 10 sieve, is best. Coarse cinder ballast is satisfactory for yard tracks and sidings and is brought to the tops of the ties to provide good footing for operating personnel. The engineering manual specifies a minimum depth of 8 inches under the ties, but as little as 4 inches can be used in hasty construction. The top of the ballast should clear the bottom of the rails by at least 1 inch. Ballast is produced locally wherever possible.

(5) *Turnouts.* The standard turnout is issued unassembled and is complete with low-stand throw and rigid-bolted number 8 frog. Dimensions and layout information for turnouts and crossovers using various frogs from number 6 to number 18 are given in figure 6-8.

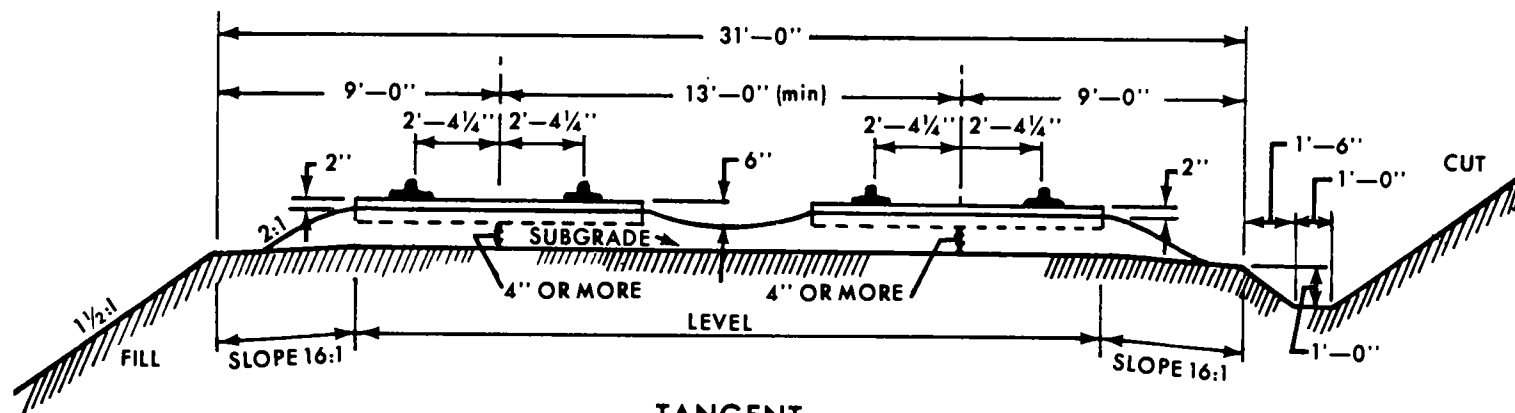
6-8. Rehabilitation

Table 6-9 reflects the rehabilitation requirements that can be anticipated for a 100-mile (161-km), standard-gage, single-track division extending inland from a port, using average percentage of demolition over the entire division. For further information, see FM 55-21.

6-9. Gage of Track

a. Standard gage of track is 4 feet $8\frac{1}{2}$ inches. That width is standard on practically every road in the United States, Canada, Mexico, the British Isles, Western Europe, Korea, Egypt, and parts of Asia. It is one of the principal gages in Australia even though there is considerably more 3 foot 6 inch gage in that country. Table 6-10 shows gages used in various countries.

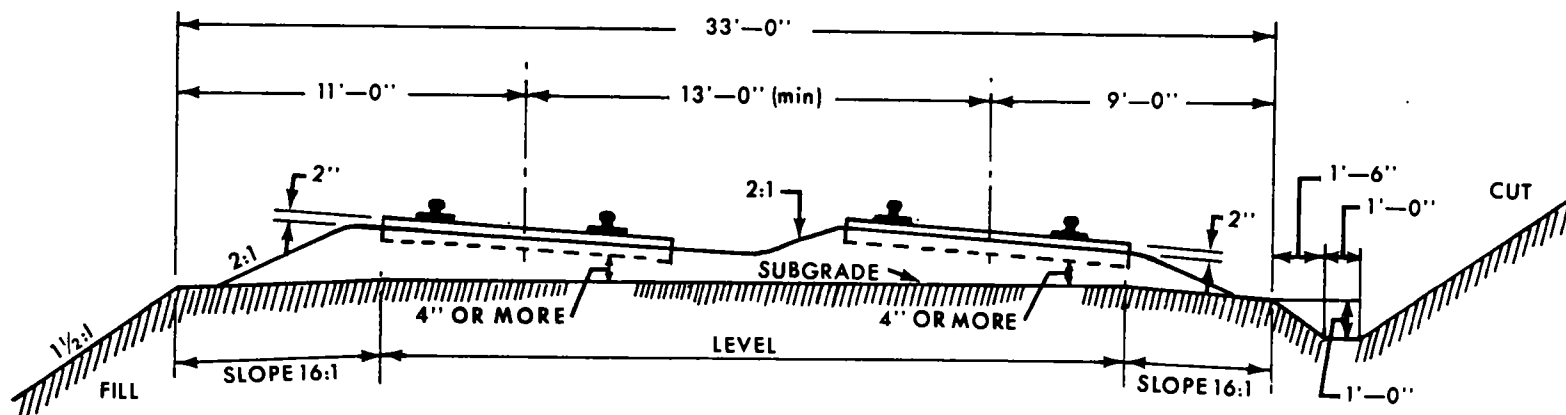
Gage of railways common to a theater of operations will probably establish the gage for existing construction. Otherwise, standard gage should be used. The gage of track should be maintained within reasonable limits. For tangent track it should not be less than 4 feet $8\frac{1}{2}$ inches nor more than 4 feet 9 inches. Variations in gage are acceptable provided they are constant over long stretches of track. On curves up to and including 13° , the standard gage of 4 feet $8\frac{1}{2}$



TANGENT DOUBLE TRACK

NOTE:

Where soil or frost conditions require,
4" to 6" of cinders, screenings or pit
run gravel sub-ballast may be installed.

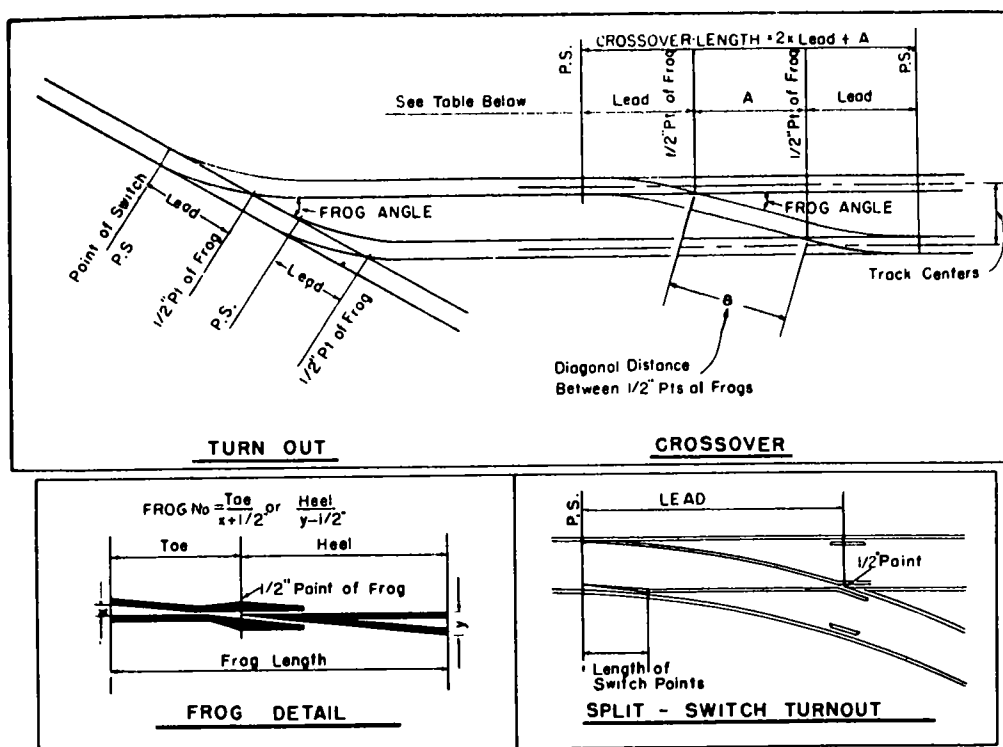


CURVED DOUBLE TRACK

NOTE:

Gage 4'-8½" on curves up to 8°,
widened ⅛" for each 2° over 8°
up to a maximum of 4'-9½".

Figure 6-7. Cross section, double track.



DIMENSIONS OF FROGS, SWITCHES, TURNOUTS AND CROSSOVERS												
FROG NO.	FROGS		SWITCHES		LEAD CURVE		TURNOUTS AND CROSSOVERS				Q $\frac{1}{2}$	
	FROG ANGLE	FROG LENGTH	LENGTH OF SWITCH POINTS	LEAD DISTANCE FROM PT. OF SWITCH TO 1/2" PT. OF FROG	RADIUS OF ℓ	DEGREE OF CURVE (Δ)	DISTANCE IN FEET BETWEEN CENTER LINES OF TRACKS—GAGE—4'-8 1/2"					
							13'-0"		14'-0"			
							A	B	A	B		
6	9°31'38"	10'-0"	11'-0"	47'-6"	258.57	22°17'58"	20'-5 1/2"	21'-6 1/2"	26'-5"	27'-7"	5'-11 1/2"	6'-0 1/2"
7	8°10'16"	12'-0"	16'-6"	62'-1"	365.59	15°43'16"	24'-0 3/8"	24'-11 5/8"	30'-11 15/16"	32'-0 1/16"	6'-11 9/16"	7'-0 7/16"
8	7°09'10"	13'-0"	16'-6"	68'-0"	487.28	11°46'44"	27'-7 1/8"	28'-4 7/8"	35'-6 3/4"	36'-5 1/4"	7'-11 5/8"	8'-0 3/8"
9	6°21'35"	16'-0"	16'-6"	72'-3 1/2"	615.12	9°19'30"	31'-1 5/8"	31'-10 3/8"	40'-1 5/16"	40'-10 11/16"	8'-11 11/16"	9'-0 5/16"
10	5°43'29"	16'-6"	16'-6"	78'-9"	779.39	7°21'24"	34'-8 1/8"	35'-3 7/8"	44'-7 13/16"	45'-4 3/16"	9'-11 11/16"	10'-0 5/16"
12	4°46'19"	20'-4"	22'-0"	96'-8"	1104.63	5°11'20"	41'-8 3/4"	42'-3 1/4"	53'-8 1/2"	54'-3 1/2"	11'-11 3/4"	12'-0 1/4"
14	4°05'27"	23'-7"	22'-0"	107'-0 3/4"	1581.20	3°37'28"	48'-9 1/4"	49'-2 13/16"	62'-9 1/16"	63'-3 1/16"	13'-11 13/16"	14'-0 1/4"
16	3°34'47"	26'-0"	30'-0"	131'-4"	2007.12	2°51'18"	55'-9 5/8"	56'-2 1/2"	71'-9 7/16"	72'-2 11/16"	15'-11 13/16"	16'-0 3/16"
18	3°10'56"	29'-3"	30'-0"	140'-11 1/2"	2578.79	2°13'20"	62'-9 7/8"	63'-2 3/16"	80'-9 11/16"	81'-2 3/8"	17'-11 13/16"	18'-0 3/16"
Δ/COLUMNS A & B UNDER Q GIVE THE AMOUNTS TO ADD TO TABULAR FIGURES FOR EVERY ONE (1) FOOT INCREASE IN DISTANCE BETWEEN TRACKS												

Figure 6-8. Frogs and switches in turnouts and crossovers.

Table 6-8. Material and Man-Hour Requirements for 1 Mile of Standard-Gage, Single-Track Railroad

	Short tons	Measurement tons	Man-hours
Grading, includes clearing average wooded terrain	---	---	5,000
Ballast delivered 5-mile (8.05 km) average haul	---	---	2,500
Track laying and surfacing, allows 400 man-hours per mile (1.61 km) for placing ties, delivered at site	---	---	3,400
Bridging: 70 linear feet (21.34 m) per mile	128	111	3,200
Culverts (7 per mile): 280 linear feet (85.34 m)	8	7	1,400
Ties: 2,900	218	300	
Rail: 90 pound ARA-A section	79	45	
115 pound, AREA section	103	57	
Fastening (based on 39-foot rail) (11.89 m)	33	10	
Total	569	530	15,500

Table 6-9. Anticipated Rehabilitation Requirements for 100 Miles of Standard-Gage, Single-Track Railroad

Item	Coast to 30 miles (48 km) inland					30 (48 km) to 100 miles (161 km) inland				
	Destruction percent	Quantity	Const materials		Const effort man-hours	Destruction percent	Quantity	Const materials		Const effort man-hours
			ST	MT				ST	MT	
1. Grading and ballast					38,200					40,500
2. Main-line trackage	20	9.6 km 6.0 mi	1,264	660	31,200	10	7.0 mi	2,708	1,033	36,400
3. Sidings (passing tracks)	80	1.9 km 1.2 mi	547	437	5,800	80	2.4 mi	1,049	874	11,500
4. Station trackage	80	1.3 km 0.8 mi	365	291	3,800	80	1.6 mi	730	582	7,700
5. Port trackage	100	4.8 km 3.0 mi	1,368	1,092	14,400					
6. Railway terminal	75	0.75 ea	8,025	4,875	160,000					
7. Culverts	15	32.0 ea	27	27	5,800	15	74 ea	63	63	13,700
8. Bridging (70 ft per mile)	75	480 m 1,575'	1,575	1,500	46,200	55	2,700 ft	2,700	2,672	70,000
9. Water station						100	3 ea	135	210	9,000
10. Fuel platform						100	1 ea	19	16	900
11. Totals			13,171	8,882	305,400			7,404	5,450	189,700

inches shall be maintained. On curves over 13°, the gage shall be widened to 4 feet 9 inches, except through crossing frogs, where standard gage shall be used.

b. The gage of frog guard rails must be carefully set. The correct distance from gage line of frog to the flangeway gage corner of the guard rail is 4 feet 6 $\frac{5}{8}$ inches. When curvature through the turnout is over 8°, the distance is always 4 feet 6 $\frac{3}{4}$ inches. The flangeway width increases as the gage is increased.

6-10. Clearances

Overhead clearances and platform heights are measured from top of rail; side clearances from centerline of track. Clearances below those specified are dangerous, and protection must be provided by appropriate warning signs or devices. For example, telltales (warning strips hung at the same height as the clearance) must be used

for overhead clearances ranging between 18 and 22 feet. Unless local conditions require greater clearances, the standard minimum clearances are as follows:

	Meters	Feet and Inches
a. Overhead.		
Wires:		
High voltage	8.53	28' 0"
Other	8.23	27' 0"
Structures	6.71	22' 0"
b. Side.		
Buildings	2.59	8' 6"
Canopies:		
Up to 15' 6"	2.59	8' 6"
Higher than 15' 6"	1.68	5' 6"
Platforms:		
3' 9"	1.88	6' 2"
4'	1.52	5' 0"
Refrigerator platforms:		
3' 2"	1.88	6' 2"
4' 7"	2.59	8' 6"

c. *Enginehouse Entrance.*

Overhead	5.18	17' 0"
Side	1.98	6' 6"

d. *Bridge and Tunnel.* Standard single-track bridge and tunnel clearances are shown in figure 6-9.

6-11. Maintenance

a. *Roadway.* Roadway maintenance is the care taken and work performed to keep that part of the right-of-way on which the track is constructed in good condition. Right-of-way includes excavations, embankments, slopes, shoulders, ditches, and diversions of roads and streams.

b. *Track.* In a theater of operations, the track must be maintained in operable condition at all times. The four primary considerations in track maintenance are gage, surface, alignment, and dress. The roadbed and track must be inspected frequently to avoid delays in operation resulting from damage caused by sabotage, direct enemy action, or weather.

c. *Structures.* In a theater of operations, the structures essential to the railway operation

must be maintained in accordance with the standard maintenance prescribed. Structures include bridges, culverts, tunnels, and fueling and watering facilities. When repairing structures, minimum clearances must be observed at all times.

6-12. Rail Shipments of Engineer Equipment

a. *Policy.* Large items of engineer motorized and other heavy construction equipment, when shipped by rail assembled or partially assembled and uncrated, are normally loaded lengthwise onto flatcars or drop-end gondolas. For dimensions of such equipment, see chapter 3. For dimensions of standard American railway cars, see FM 55-15. For preparing engineer TOE equipment loading plans, see TB 55-46.

b. *Number of Items Per Car.* To find what fraction of a car the item will occupy, divide the length of the car into the length of the item, plus a small allowance for clearance.

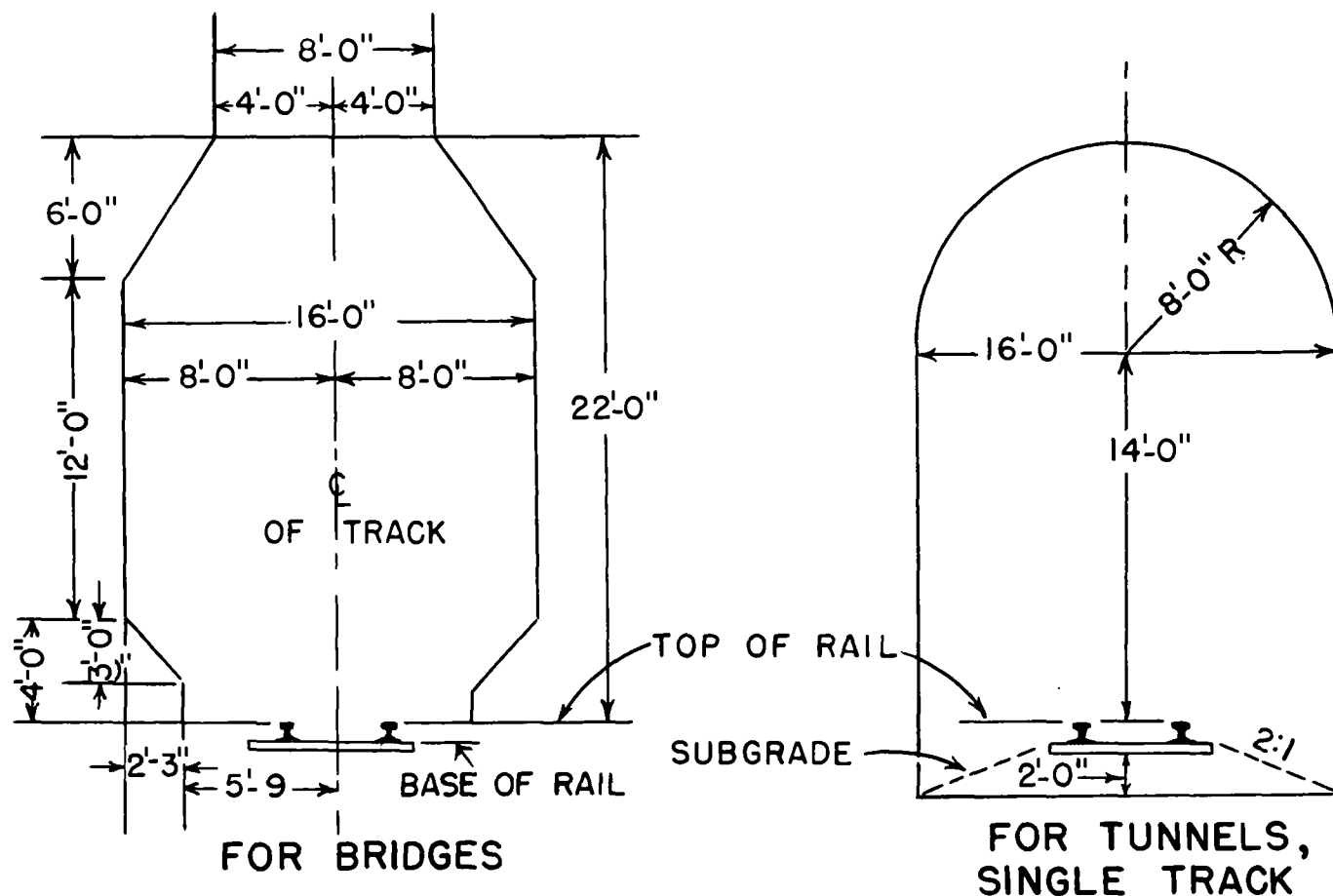


Figure 6-9. Standard single-track bridge and tunnel clearances.

Table 6-10. Railway Systems of Various Countries

Country	Service commenced	Ownership ¹	Gage ²	Mileage ³	
				Route length	Track length
Argentina	1857	state	5' 6"	14,882	19,687
Australia	1854	state	standard ⁴	7,163	9,725
Austria		state	standard	3,372	6,135
Belgium	1835	state	standard	2,787	7,673
Brazil	1854	state	meter		16,105
Bulgaria	1866	state	standard	3,337	
Canada	1836	state	standard	23,787	34,964
		private	standard	16,641	23,443
Ceylon	1865	state	5' 6"		
China	1881	state	standard	23,900	
Czechoslovakia		state	standard	12,030	12,202
Denmark	1847	state	standard	1,461	2,974
Egypt	1854	state	standard		
Finland	1862	state	5'		
France	1828	state	standard	22,984	49,474
Germany	1835	state	standard	18,645	42,253
Greece		state	standard	969	1,260
Hungary	1846	state	standard	5,030	8,793
India	1853	state	5' 6"	17,767	34,128
Indonesia		state	3' 6"		
Ireland	1834	state	5' 3"	1,333	1,915
Italy	1839	state	standard	10,271	17,699
Japan	1872	state	3' 6"	12,906	24,225
Korea		national	standard	1,885	3,042
Mexico	1850	state	standard	9,442	12,478
Netherlands	1839	state	standard	2,004	4,437
New Zealand	1863	state	3' 6"		
Norway	1854	state	standard	2,670	3,408
Pakistan			5' 6"	5,189	7,676
Poland	1845	state	standard	14,518	
Portugal	1856	state	5' 6"	1,760	2,386
South Africa	1860	state	3' 6"	13,435	
Spain	1848	state	5' 6"	8,303	11,705
Sweden	1856	state	standard	7,212	11,130
Switzerland	1844	state	standard	1,823	4,088
Turkey		state	standard		
United Kingdom		state	standard	13,172	36,498
United States	1830	private	standard		
U.S.S.R.	1837	state	5'	82,779	
Yugoslavia		state	standard		10,213

¹ Predominant ownership is given; most countries have both private and state-owned lines.

² Gage of the principal mileage; most countries have lines of several gages.

³ Data are for 1969-70.

⁴ Standard gage = 4' 8½".

c. Loading on Flatcars.

(1) For American mainline railroads and for a flatcar whose deck is 3 feet 6 inches above the top of the rail (the most common height), the following are the maximum permissible widths, at various heights, of any item loaded on the car:

At a height, above car floor, of—	Maximum permissible width
0 feet (car floor)	10 feet 8 inches
10 feet 3 inches	10 feet 8 inches
10 feet 9 inches	10 feet 0 inches
11 feet 7 inches	7 feet 0 inches

If the car deck is higher than 3 feet 6 inches, figures in the first column must be reduced by the amount in excess of 3 feet 6 inches.

(2) For shipments on branch lines, somewhat lesser maximum heights and widths may have to be used. Clearance diagrams should be consulted before loading equipment.

d. Loading on Gondolas. Information in c above applies, with the qualification that, from the level of the car deck up to the top of the sides, the maximum permissible width of a loaded item is 6 inches less than the clear inside width of the car. This latter is usually 9 feet 0 inches to 9 feet 6 inches, though in some cases it may be as much as 10 feet 0 inches.

Section III. BRIDGES, RAFTS AND CABLEWAYS

6-13. References

TM 5-312 is the principal reference for fixed military bridges, both highway and railroad. TM 5-302 includes some standard bridge designs. Through truss railway bridges are covered in TM 5-373 and TM 5-374 deals with light standard and standard unit steel trestles. TM 5-277 covers the Bailey Bridge, TM 5-210 and FM 5-34 cover floating bridges. TM 5-270 covers cableways, tramways and suspension bridges. Factors for estimating material and man-hour requirements for bridge construction appear in FM 101-10-1. FM 5-36 and the Bridge Classification Card, GTA 5-7-7, provide guidance for reconnaissance and classification of bridges.

6-14. Engineer Functional Components System

a. General Concept. The EFCS is a valuable tool for operations and planning officers in selecting the most suitable highway or railway bridge design for a specific site. This system offers a wide variety of bridge designs, with construction details, bills of materials, labor estimates, material costs and logistical data. EFCS related publications are—

(1) *TM 5-301, Staff Tables of EFCS.* This manual explains the concept and use of the system. Logistical data (cost, weight and volume) and construction estimates are included.

(2) *TM 5-302, Construction in the Theater of Operations.* Of the three EFCS manuals, this

is the most useful to construction units. It contains layout drawings, standard and special detail drawings, and simplified bills of materials.

(3) *TM 5-303, Bills of Materials and Equipment of the EFCS.* This manual contains the complete bill of material for each equipage in the EFCS. It may be used as a guide to develop bills of materials or the published bills may be used to requisition materials with items added or subtracted as desired.

b. Coding. Items in the EFCS are coded for identification by a six-digit number. For example, 852102 identifies a road bridge superstructure, double lane, class 60 laminated floors, 6-27 WF beams, length 37' 4½"—39' 2¼". The first two digits identify the major groupings; highway bridging is identified by the digits 85 and railroad bridging by the digits 86. The first four digits identify the drawing number in TM 5-302. In the example cited above, the drawing for the superstructure is identified by drawing number 85-21 in TM 5-302.

c. EFCS Bridge Listing. Highway and Railroad bridges listed in the EFCS are the 30- and 60-foot I-beam highway spans, the 17-, 21-, 27- and 35-foot I-beam railroad spans, the unit construction deck and through type railroad spans, the through truss railroad spans, and the highway and railroad bridge designs employing the use of 27 and 36 inch wide flange beams and 48 inch deck plate girders. All conversion sets applicable to these bridges are also included. So-

Table 6-11. Reconnaissance and Assault Boat Data

Item	Use	Description	Capacity	Remarks
Three-man reconnaissance boat.	Reconnaissance ...	Canvas w/5 compartments issued with towline and 3 paddles. Total weight 30 lb.	3 men in current Speeds up to 4 KMPH.	Boat is breath-inflated or hand pumped. Easily carried by one man when deflated and packed in case.
Plastic assault boat ...	Initial crossing	Plastic, hand paddled Weight 300 pounds Length 16' 5" Width 5' 4".	12 Infantrymen w/full equipment or equivalent in current speeds up to 4 KMPH.	Normal crew, three engineers. Maximum capacity w/no current is 3,300 pounds. Can be propelled by one 25-hp outboard motor at speed of 12.8 KMPH w/o a load reduction.
Assault boat pneumatic.	Assault crossing	Neoprene coated nylon, pneumatic, weight 250 lb, length 17 feet, width 5' 8".	12 fully equipped infantrymen, crew three engr.	18 in Div. Engr. Bn. Can be paddled or power supplied by 25-BHP motor 13 KMPH in current of 7 KMPH. 70 at Corps/Army Float Bridge Co.

lutions for spanning gaps with nonstandard designs and employing raw beams currently in the inventory, are also covered by the EFCS.

6-15. Floating Bridges

a. Light Equipment. Military floating bridge and stream crossing equipment is generally categorized as light or heavy. Light stream crossing equipment includes; the 3-man reconnaissance boat (table 6-11), the plastic assault boat (table 6-11), the assault boat, pneumatic (table 6-11), the aluminum floating footbridge (table 6-12), and the light tactical raft/bridge (tables 6-13 and 6-14).

b. Heavy Equipment. Heavy stream crossing equipment includes; the M4 bridge and rafts,

class 60 bridge and rafts, M4T6 bridge and rafts, 19- and 27-foot bridge erection power boats, the amphibious river crossing equipment (ARCE), and the mobile float assault bridge (MAB). Table 6-15 gives the weight class of the principal heavy float bridges under different conditions. Table 6-16 gives the classes of rafts constructed from the heavy float bridge equipment. Table 6-17 gives capacities of the ARCE rafts and table 6-18 the capacities of the MAB rafts.

6-16. Cableways and Tramways

Logistical data and other characteristics of cableways and tramways are shown in table 6-19. Figures 6-10 through 6-13 illustrate details and typical installations.

Table 6-12. Aluminum Footbridge Data

Bridge set	Basis of issue	Suggested working party		
		Detail	NCO	EM
Normal assembly: 472 ft 6 in.	One set to each engineer float bridge company*.	Near-shore anchor cable -----	1	6
Light vehicle bridge: 100 ft.	Vehicles required for transportation of bridge set:	Far-shore anchor cable -----		7
		Bridle line -----		2
Expedient rafts: 3	Two, 2½-ton 6 x 6 cargo trucks with	Guy line -----	1	5
Major items:	2½-ton pole type trailers or 3, 2½-	Shore assembly -----		6
	ton cargo trucks.	Assembly carrying -----		6
Ponton 42		River assembly -----	1	4
Treadways 42		Handrail -----		3
		Plus 2 EM per 100 ft of bridge		

*Also one set to each Airborne Engineer Bn.

Table 6-13. Light Tactical Raft Capacities

Type of raft	Number of pontoons or floats	Overall length of raft	Stream velocities in feet per second for specified crossing									
			Normal crossing					Risk crossing				
			5	7	8	9	11	5	7	8	9	11
Light Tactical Raft With Articulators.	4 Pontons	58'	12	12	12	8	0	14	14	14	12	4
	3 Bays											
	5 Pontons	80'	9	9	9	8	3	11	11	11	11	6
	5 Bays											
	6 Pontons	69'	13	13	13	13	6	15	15	15	15	10
	4 Bays											

Table 6-14. Data on Floating Bridge Construction From LTR Set

Type of bridge	Type of crossing	Stream velocities in feet per second for specified assembly					
		Normal					
		3	5	7	8	9	11
Light tactical raft floating bridge.	Normal	16	16	13	11	8	2
	Caution	18	18	15	12	9	3
	Risk	21	21	17	14	11	5

Table 6-15. Classes ¹ of Floating Bridges

Stream velocities in feet per second ; meters per second for specified assemblies													
Type of bridge	Type of crossing	Normal						Reinforced ²					
		3 0.9	5 1.5	7 2.1	8 2.4	9 2.7	11 3.3	3 0.9	5 1.5	7 2.1	8 2.4	9 3.8	11 3.3
M4 ¹	Normal	60	60	45 50	45 45	30 35	18 20	95	95	75 80	60 65	45 50	24 27
	Caution	68	65	56 59	52 53	44 46	29 31	100	100	88 99	75 85	62 74	35 37
	Risk	72	68	61 62	58 59	53 54	37 39	105 100	105 100	101 96	88 85	74 73	45 46
Class 60 ⁴	Normal	60 65	55 65	45 55	40 50	35 45	22 25	65	65	65	65	65	30 35
	Caution	65 70	62 67	56 61	52 56	45 49	34 37	75	75	75	75	75	47 51
	Risk	75 79	72 77	67 72	62 67	57 62	46 50	85	85	85	85	85	70 74
M4T6 ³	Normal	50 55	45 55	40 50	35 45	30 40	25 30	75	75	70 75	65 70	55 60	27 30
	Caution	60 61	58 59	54 55	49 51	45 47	35 37	80	80	79	73	66 67	43 45
	Risk	68 69	66 67	62 63	59 60	54 56	43 45	90	90	90	87	81	59 60

¹ Based on abutment deck level within 18" of floating bridge deck level except for hinged or other special end spans. Where limitations are exceeded, capacities must be reduced.

² Reinforced by placing 3 floating supports under 2 bays of decking. (50% reinforced)

³ Capacities based on roadway width of 18 balk and deck width of 22 balk. Reinforced assembly requires a 38' 4" superimposed end span.

⁴ Reinforced bridge capacities up to 9 fps are controlled by end span limitations.

Table 6-16. Classes¹ of Rafts

Type of raft	Number pontons or floats	Overall length of raft	Stream velocities in feet per second, meters per second for specified crossings									
			Normal Crossing					Risk Crossing				
			5	7	8	9	11	5	7	8	9	11
			1.5	2.1	2.4	2.7	3.3	1.5	2.1	2.4	2.7	3.3
Light Tactical Raft With Articulators	4 Pontons 3 Bays	5'8"	12	12	12	8	0	14	14	14	12	4
	5 Pontons 5 Bays	80'	9	9	9	8	3	11	11	11	11	6
	6 Pontons 4 Bays	69'	13	13	13	13	6	15	15	15	15	10
M4 ²	4 Normal	87'1"	50 55	50 55	50 55	50 55	40 45	55 60	55 60	55 60	55 60	45 50
	6 Partially Reinforced	87'1"	70 75	70 75	65 70	65 70	50 55	75 80	75 80	75 80	75 80	55 60
	7 Fully Reinforced	87'1"	85 90	85 90	80 85	80 85	55 60	90 95	90 95	90 95	90 95	65 70
Class 60	4 Normal	92'5"	40 45	40 45	35 40	35 40	25 30	50 55	50 55	45 50	45 50	35 40
	5 Normal	107'5"	50 55	50 55	45 50	40 45	30 35	60 65	60 65	55 60	50 55	40 45
	5 Partially Reinforced	92'5"	55 60	50 55	50 55	45 50	35 40	60 70	60 65	60 65	55 60	45 50
	5 With 1 Short Deck Bay Rein.	83'1"	60 65	55 60	55 60	50 55	45 50	65 75	65 70	65 70	60 65	55 60
	6 Fully Reinforced	92'5"	65 75	65 75	60 70	60 65	50 55	80 90	80 90	75 85	70 80	60 70
M4T6 ²	4 Normal	87'	50 55	45 50	40 45	35 40	30 35	60 65	55 60	50 55	45 50	35 40
	4 Reinforced	86'	50 55	50 55	45 50	40 45	35 40	60 65	60 65	55 60	50 55	45 50
	5 Normal	101'	55 60	50 55	45 50	40 45	35 40	65 70	60 65	55 60	50 55	45 50
	5 Reinforced	88'9"	60 60	60 60	55 60	45 50	45 50	70 75	70 75	65 70	65 70	55 60
	6 Reinforced	103'4"	65 70	65 70	65 70	60 65	45 50	75 80	75 80	75 80	70 75	55 60

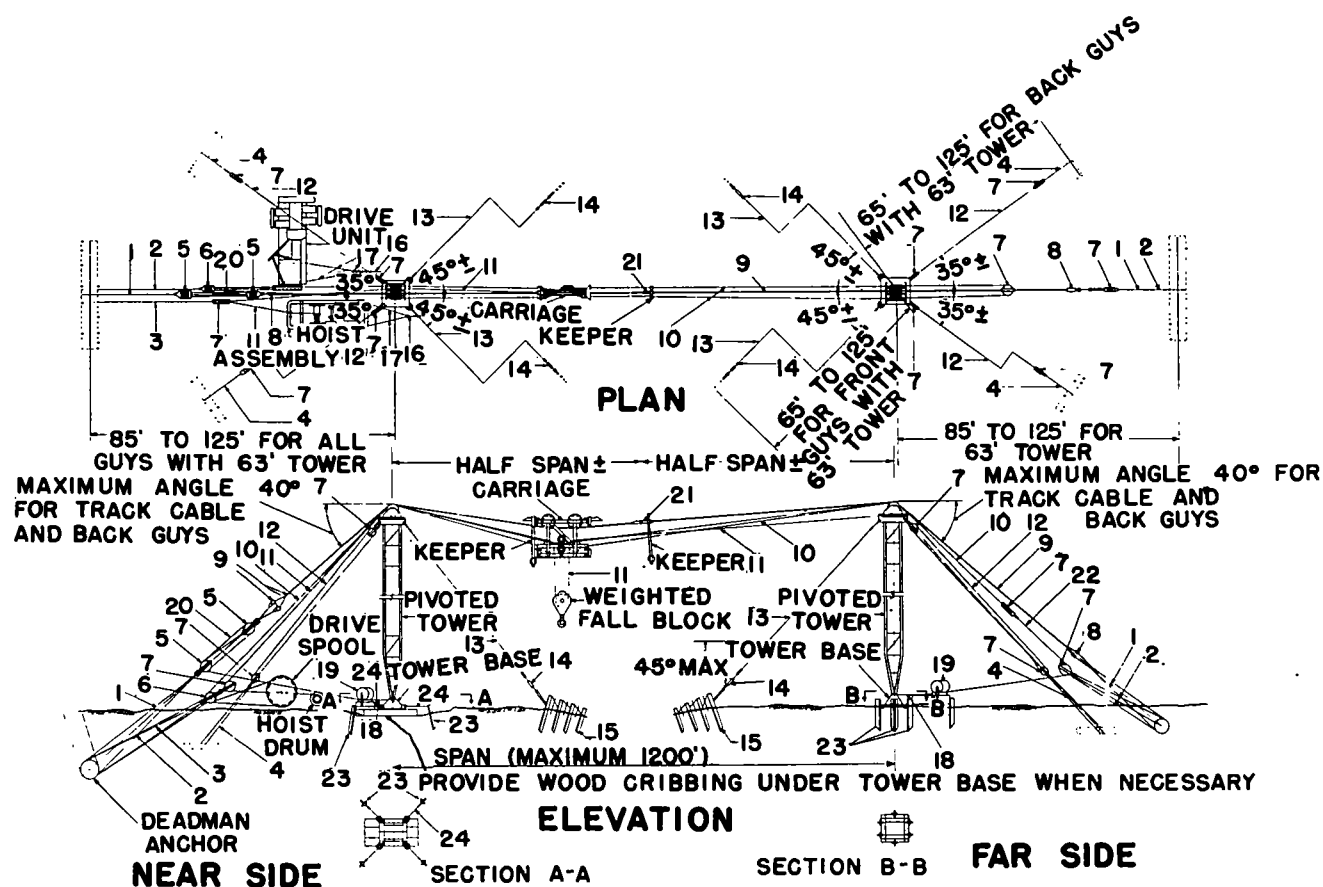
¹ Based on loading rafts with center of gravity of loads 6 inches downstream from centerline of raft and on properly inflated floats.² Capacities based on roadway width of 18 balk, deck width of 22 balk and on 18 or 19 feet end span.

Table 6-17. ARCE Raft Capacities

Raft construction	Current velocity FPS MPS		
	0-4.9 0-1.5	5.0-6.6 1.5-2.0	6.7-8.2 2.0-2.5
2 Unit	55	49.5	44
3 Unit	88	80.3	71.5
4 Unit	121	110	99

Table 6-18. MAB Raft Capacities

Raft construction	Classification in current up to 8 MPH/12.9 KPH
2 end bays	25
3 bays	40
4 bays	60
5 bays	75
6 bays	90



1. $\frac{3}{8}$ -inch cable for track-cable anchor, (2 parts)
2. $\frac{1}{2}$ -inch cable for haul-rope anchor, (2 parts)
3. $\frac{1}{2}$ -inch cable for fall-rope anchor, (2 parts)
4. $\frac{1}{2}$ -inch cable, (2 parts)
5. Triple block
6. Double block
7. Single block
8. Cable grip, wedge type
9. $\frac{3}{8}$ -inch track cable, 6x19, 750 feet
10. $\frac{3}{8}$ -inch haul rope, 6x19, IPS
11. $\frac{3}{8}$ -inch fall rope, 6x19, IPS
12. $\frac{1}{2}$ -inch guy cable, 6x19, IPS, 300 feet
13. $\frac{3}{8}$ -inch guy cable, 6x19, IPS
14. $\frac{3}{8}$ -inch wedge socket, $\frac{3}{4}$ -inch J and E turnbuckle
15. Steel picket halldfast
16. Halldfast
17. $\frac{3}{8}$ -inch cable sling
18. Hand-winch anchor assembly
19. Hand winch, 5-ton
20. $\frac{1}{2}$ -inch cable, 6x19, 400 feet
21. Wire-rope coupling
22. $\frac{1}{2}$ -inch cable, 6x19, IPS, for adjusting tension in haul rope
23. Stakes
24. $\frac{3}{8}$ -inch cable, (2 parts)

Figure 6-10. Medium cableway.

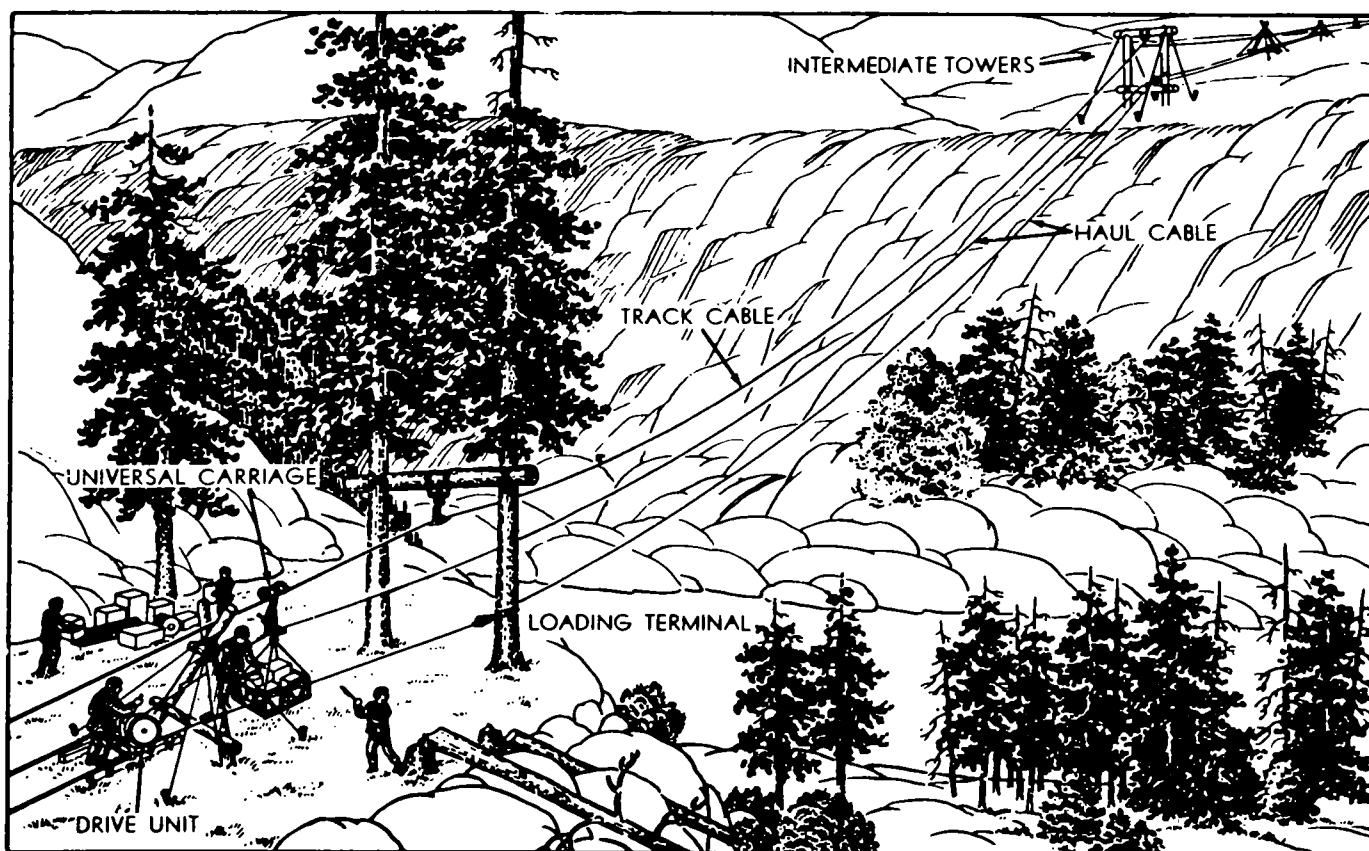


Figure 6-11. Pioneer light aerial tramway, M1.

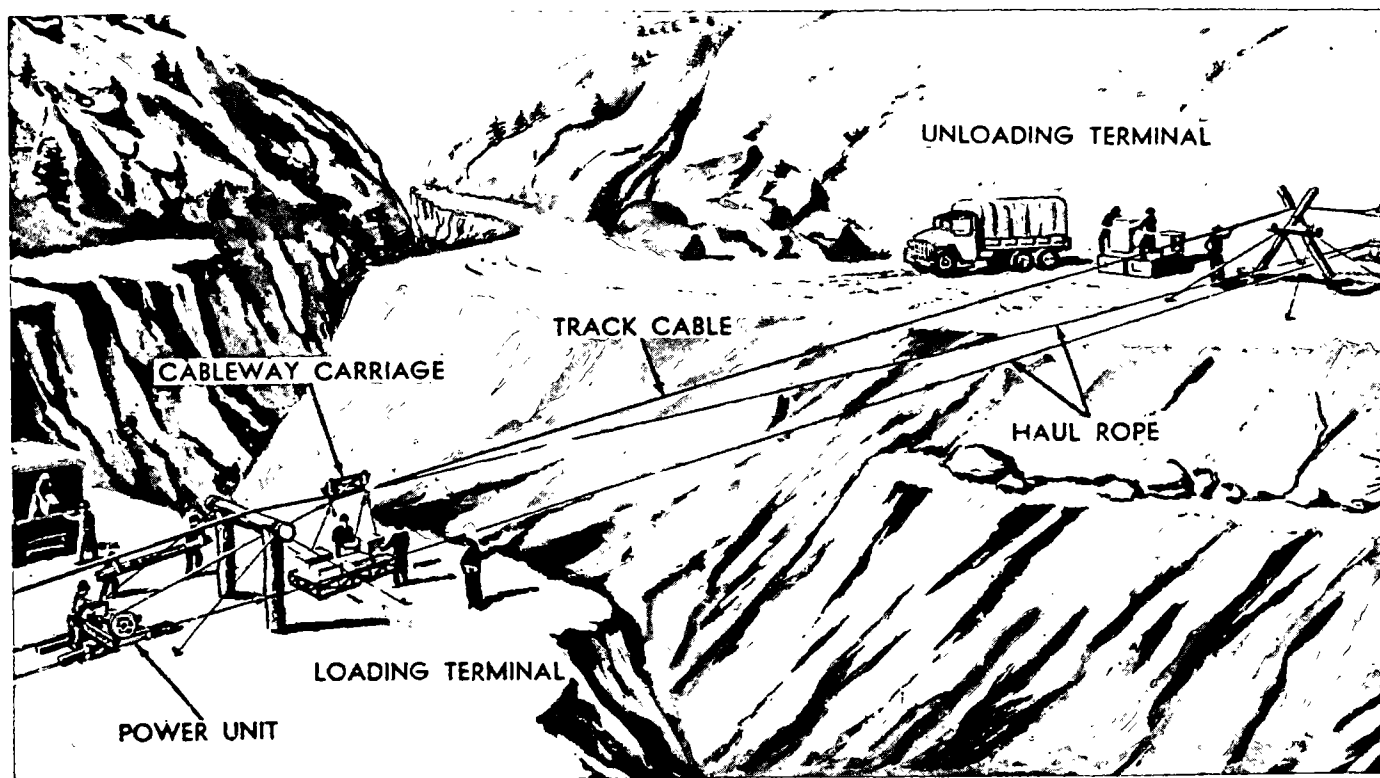


Figure 6-12. Light aerial cableway, M1.

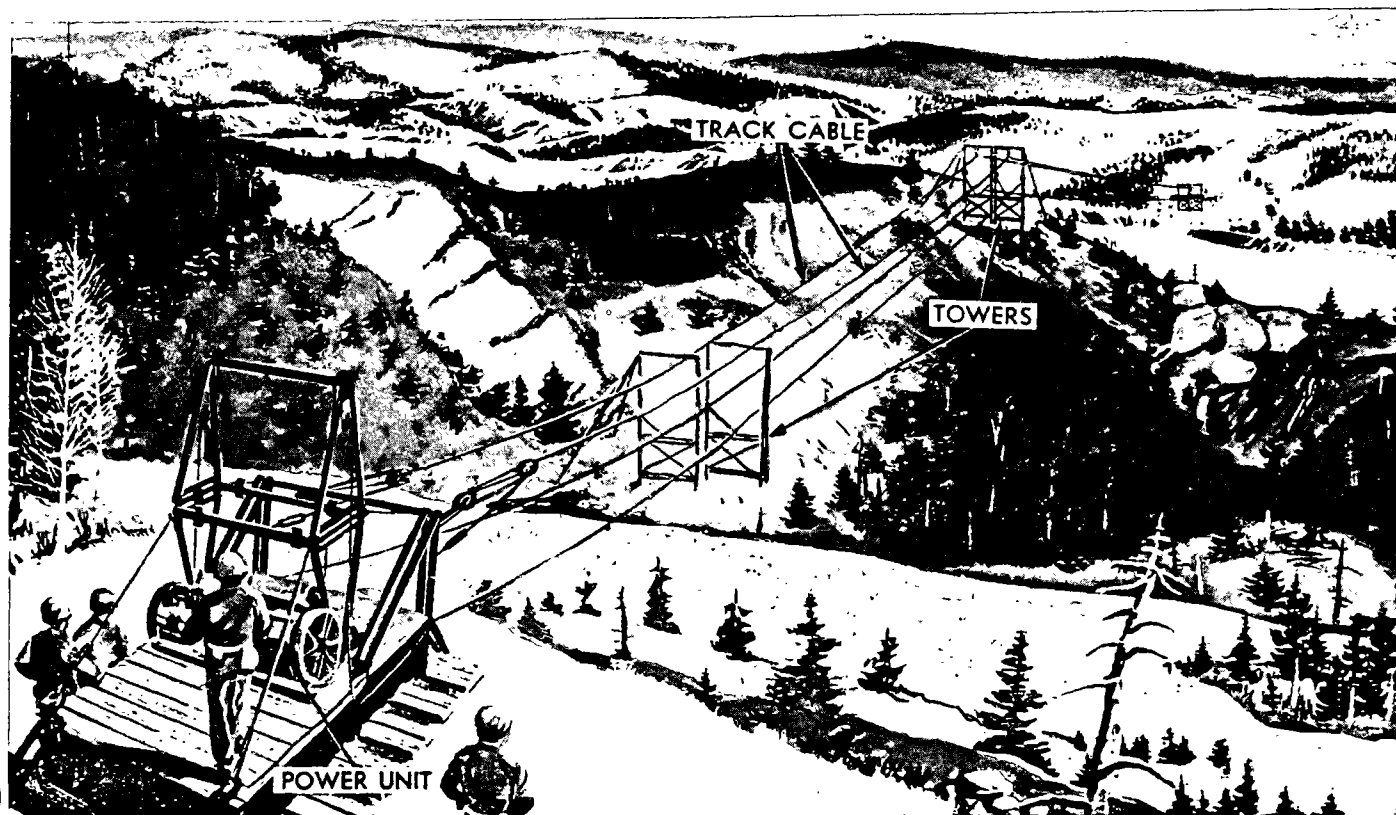


Figure 6-13. Light aerial tramway, M2.

Table 6-19. Logistical Data and Other Characteristics of Cableways and Tramways

Type	Issue	Composition	Transportation	Capacity	Length	Construction	
						Personnel	Time
Medium cableway ----	Class IV	2 sectionalized towers 1 carriage 2 keepers 1 power unit 1 hoist unit Accessories, tools, and tackle.	4 2½-ton trucks	Carrier load 3,000 pounds; approximately 17 tons per hour, over 1,000 ft gap.	1,200 ft	2 platoons	5 hr
Pioneer light aerial tramway and cableway, M1.	Class IV	2 cableway carriages 6 tramway or cableway carriages. 3 tramway carriers (7 ft). 1 power unit toboggan.	1 2½-ton truck or 4 ¾-ton trucks.	Tramway-carrier load 350 pounds.	2,000 ft	2 platoons	10 hr
				Cableway-carrier load 2,000 pounds approximately 10 fps.	1,500 ft	1 platoon	5 hr
Light aerial tramway, M2 (extension set also available).	Class IV	1 lower terminal 1 upper terminal Intermediate towers. 1 power unit 4 carriers Accessories, tools, and tackle.	4 2½-ton trucks or 12 ¾-ton trucks.	Carrier load 350 pounds approximately 1 ton per hour over 3,000 ft length.	3,000 ft	1 company	24 hr

CHAPTER 7

PORT CONSTRUCTION, SHIPS, AND AMPHIBIANS

Section I. PORTS

7-1. Responsibilities

a. Theater and Zone Commanders. The general responsibilities of the theater commander, the theater army commander, and the commander of the communications zone are stated in FM 100-10. The functions of the higher echelon commands for the construction of a specific port include—

(1) Studies of intelligence reports and of all available reconnaissance applying to each port area which is considered for use.

(2) Tentative determination of the ports or coastal areas to be used as a part of the overall strategic planning.

(3) Assignment of the mission of the port.

(4) Determination of port requirements.

(5) Tentative decision on the general methods of construction to be used, and determination of engineer units, special equipment, and material required.

b. Engineer Units. Engineer units are responsible for port construction and rehabilitation and for coordinating all work with that of any naval units engaged in harbor clearance and salvage operations or in the neutralization of mines or underwater obstacles in the harbor area. Transportation units, which operate the port facilities, coordinate and assist in establishing construction requirements, in planning the construction, and in recommending the priorities to be assigned. In performing its mission of rehabilitation, construction, and maintenance of a port the engineer unit is responsible for—

(1) Construction and rehabilitation to keep abreast of changing conditions.

(2) Requisitioning of the supplies and equipment required to carry out its mission.

(3) Liaison with naval units to coordinate construction with harbor clearance activities.

(4) Recommendations for the assignment of seized areas and facilities within the port area.

(5) Advising the logistical commander and

staff on engineering matters connected with the identification, classification, in-transit storage, movement, and distribution of engineer equipment and class I construction materials.

(6) Continuous study of the port situation and preparation of tentative plans for possible contingencies.

(7) Construction and maintenance of roads and structures in harbors and inland waterways.

(8) Construction, and major maintenance only, of railway facilities required by the port.

(9) Construction, and major maintenance only, of tanker unloading facilities.

(10) Maintenance and operation of the fire-fighting facilities of the port.

(11) Water supply.

c. Transportation Units. In performing the mission of operating an oversea port as a facility to provide for the reception, debarkation, embarkation, and transshipment of troops, animals, supplies, and material, transportation units are responsible for—

(1) Operating the port.

(2) Coordination of operational activities with the carrying out of necessary projects.

(3) Providing liaison with Navy and Coast Guard.

(4) Continuous study of the needs of the port facilities to insure the smooth and orderly flow of personnel, supplies, and material through the port.

(5) Planning, supervising, and controlling the movement from the port of all freight by rail, motor and inland water transportation and, under certain conditions, air transport.

d. Quartermaster Units. The quartermaster units have overall responsibility for the operation of petroleum pipeline systems to include off-vessel discharging and loading. They coordinate with naval units, engineer units, and transportation units in determining the location of tanker unloading and vessel refueling facilities.

7-2. Definitions and Criteria

a. Harbor. A partially enclosed body of water, natural or artificial, which provides protection for vessels to load or unload.

b. Port. A harbor with constructed facilities for loading, unloading, removal, and possibly storage of materials.

c. Wet Dock. A basin of water used as a place of shelter for a vessel, with artificial entrance gate which permits some control of the level of water within the basin.

d. Wharf. A marginal structure for the berthing of ships—may be a marginal quay or off-shore marginal wharf.

e. Pier. A structure that projects from the shore toward the center of the waterway to provide berthing spaces for ships. Basic types are square pier, square pier and slip system, and angle pier and slip system.

f. Breakwater. A protective barrier system to break up and disperse heavy seas. They are typed by construction, i.e., rubble mound, masonry or precast concrete, timber crib, timber pile, and sheet pile.

g. Jetty. A structure placed at the entrance of a harbor or river, diverting or directing existing currents to create or protect a selected channel. Rubble mound jetties are the most common type.

h. Mole. A breakwater or jetty that serves the mission of both protection and berthing facility.

i. Groin. Basically, a small breakwater and jetty, combined. Groins are classified as permeable, impermeable, and semipermeable and are used when harbor conditions do not require massive structures.

j. Bulkhead (quay wall). A vertical retaining structure along a shore or used to form the face of a quay. It provides support or protects areas of shore or fill from erosion.

k. Sea Wall. A vertical or sloping wall which offers protection to the shore against wave damage or erosion.

l. Dolphin. Isolated clusters of piles to which ships may be moored. Contains kingpile(s) for mooring, and batter piles for protection of kingpile(s). May be used individually, in groups, or to extend piers or jetties.

m. Fathom. A measurement of depth. Harbor and channel depths are measured in fathoms. (1 fathom = 6 feet).

n. Port Capacity. The estimated amount of dry cargo, bulk and rolloff equipment, usually expressed in weight or measurement tons per day, that can be discharged from ships or lighters with the available piers, wharves, quays, jetties, moles, beaches, and so on of a port.

o. Width. Standard minimum width for wharves for deep-draft ships using one-side discharge is 60 feet; two-side discharge, 90 feet. For lighterage discharge the corresponding widths are 35 and 42 feet.

p. Length. Wharf length should allow 100 feet for each hatch or each lighter to be discharged. The discharge rate for ships is reduced by 20 to 25 percent for each 100 feet reduction in wharf length below this criteria.

q. Depth. Minimum required depth below mean low water is the depth required by the draft of a ship. For deep-draft ships, the minimum required depth is 30 feet; for shallow-draft craft, 12 feet or less.

r. Wharf Systems. Wharf systems are extensions built from shore to water of minimum required depth to provide direct contact for handling cargo between deep- or shallow-draft ships and shore. In this manual the word wharf includes any structure intended for this purpose, and thus includes structures otherwise described as quays, piers, or marginal wharves.

7-3. Wharf Layouts and Berthing Space

Figure 7-1 illustrates the most common types of wharf layouts with appropriate terminology. Table 7-1 gives the berthing space for ships and lighters per 1,000 feet of shore front for each wharf type shown in figure 7-1.

7-4. Earth-Fill and Pile Wharfs

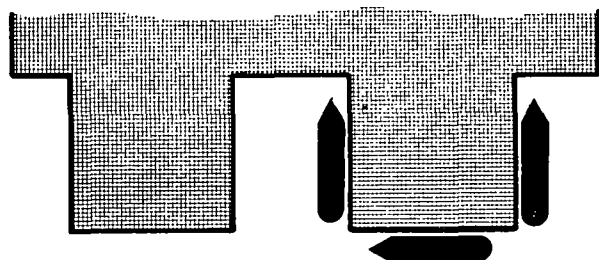
a. References. Details of design and construction of the most commonly constructed earth-fill and pile wharfs are covered in TM 5-302 and TM 5-360.

b. Earth-Filled Wharf Structures. Earth-filled structures are often the most simple and rapid means for providing wharfage. Bulkheads or retaining walls are required to retain the fill and provide a vertical face with adequate water depth alongside. The most common types of bulkheads are:

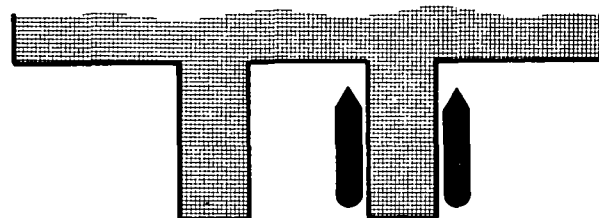
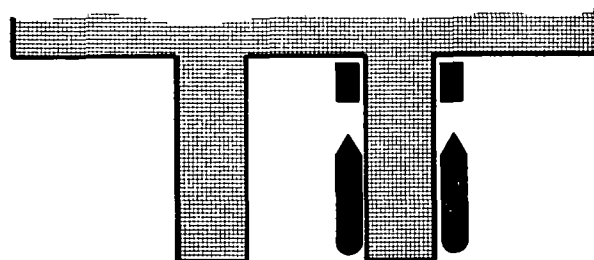
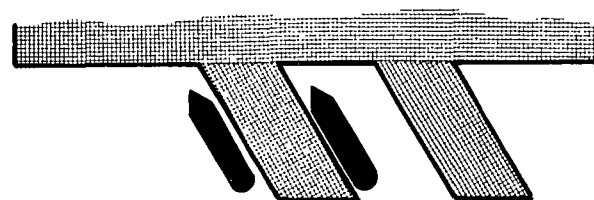
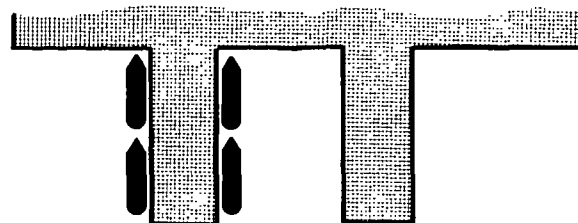
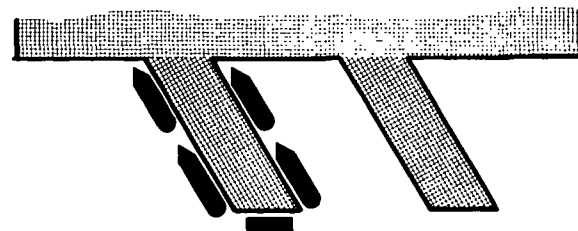
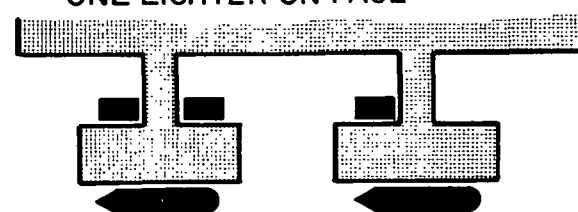
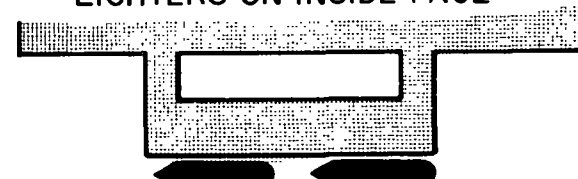
- (1) Masonry walls.
- (2) Sheet pile bulkheads.
- (3) Expedient structures such as rock-filled timber cribs, rock-filled barges, or sunken and anchored ponton structures.



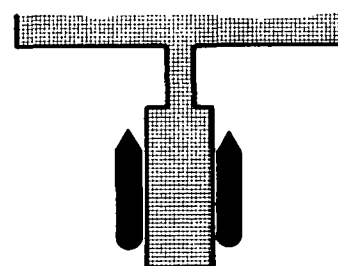
① QUAY



② SQUARE PIER

③ RIGHT-ANGLE PIER
ONE FREIGHTER EACH SIDE④ RIGHT-ANGLE PIER
ONE FREIGHTER-ONE LIGHTER
EACH SIDE⑤ ACUTE-ANGLE PIER
ONE FREIGHTER EACH SIDE⑥ RIGHT-ANGLE PIER
TWO FREIGHTERS EACH SIDE⑦ ACUTE-ANGLE PIER
TWO FREIGHTERS EACH SIDE
ONE LIGHTER ON FACE⑧ T-TYPE MARGINAL WHARF
FREIGHTER ON OUTSIDE FACE
LIGHTERS ON INSIDE FACE

⑨ U-TYPE MARGINAL WHARF

⑩ FINGER PIER
ONE FREIGHTER EACH SIDENOTE:

NOT TO SCALE. FOR EXPLANATION OF LAYOUT TERMINOLOGY ONLY

Figure 7-1. Types of wharf layout.

Table 7-1. Linear Feet of Berthing Space Per 1,000 Feet of Shore Front

Type of layout	Freighter	Lighter	Total
(1) Quay	1,000	-----	1,000
(2) Square pier	2,143	-----	2,143
(3) Right-angle pier for one freighter on each side	3,120	313	3,433
(4) Right-angle pier for one freighter plus one lighter on each side	3,120	1,250	4,370
(5) Acute-angle pier for one freighter on each side	2,690	270	2,960
(6) Right-angle pier for two freighters on each side	4,160	208	4,368
(7) Acute-angle pier for two freighters on each side	3,600	180	3,780
(8) T-type marginal wharf for freighter on outside face and lighters on inside face	770	*1,380	*2,150
(9) U-type marginal wharf	1,000	-----	1,000
	or less.		or less.
(10) Finger pier	3,120	**313	**3,433

Note. These figures are for purposes of comparison only. (See fig. 7-1)

*1,682 feet and 2,452 feet if traffic conditions are such that lighters can be worked along the faces of the causeway.

**Up to 813 feet and 3,933 feet if traffic conditions are such that lighters can be worked along the faces of the causeway.

Figure 7-2 illustrates construction of a typical earth-filled quay.

c. *Pile Wharves.* In a pile wharf, the pile transmits the load to the ground. Pile may be of timber, steel, or concrete, and may, especially in repair or rehabilitation, be a composite of these materials. Pile construction permits flexibility in wharf layout. Figure 7-3 shows the construction of a typical timber pile wharf.

7-5. Self-Elevating Barge Wharfs

a. *Introduction.* A self-elevating barge consists of a *barge unit*; a number of *pneumatic jacks*, *control panels*, and *caissons*; and *miscellaneous equipment*. The barge unit is of prefabricated steel construction and forms the surface, or deck. The caissons are welded steel tubes which are fitted into wells in the barge unit and provide it support in the manner of piles. Pneumatic jacks are fitted on each caisson, and by means of control panels, raise and lower the barge unit as required. Miscellaneous equipment such as cranes, power boats and/or tugs, etc. are required in moving and construction. Further accessory equipment may or may not be required, depending on the type of installation desired. One or more self-elevating barges can be used to construct a wide variety of piers or wharves. It is frequently erected as a marginal wharf at some distance off shore. In this case, some means must be provided for transporting supplies from pier to shore. Six sizes of prefabricated steel barge units have been adopted for military use (table 7-2). Figure 7-4 shows two barge units installed as a finger pier. Figure 7-5 gives plan and elevation views of the 300' x 80' x 13' barge unit. Detailed descriptions and erection procedures are covered in TM 5-360 and TB 5-360-1.

b. *Uses and Advantages.* The design of the barge allows it to be towed from a preparation site to its point of erection. Once preparation is completed, that is, compressors started and caissons laced, the self-elevating barge can be moved from harbor to harbor, providing ports to follow the course of battle. Prepared self-elevating barges can be erected within 24 hours of arrival at a chosen port. Preparation takes from 1 to 2 weeks.

c. Installation Considerations.

(1) Tide information must be available since pier designs are based on a height of about 5 feet from mean high water to wharf deck.

(2) Wave heights under 3 feet will cause little difficulty. Waves from 3 to 5 feet require extra care to insure that the barge does not shift position during installation. If the wave height exceeds 5 feet, extreme caution must be taken to insure that the barge remains in place and that the equipment stowed on the barge is lashed securely.

(3) Since the barge is supported by caissons that act as piles, soil tests must be accomplished. The most reliable is by means of a pile load test. The type of soil best suited for erection of the self-elevating barge pier is composed of

Table 7-2. Barge Unit Data

FSN	Size	Pneumatic jack size
1945-575-0570	45' x 56' x 6'	100 T
1945-999-7900	150' x 60' x 10'	500 T
1945-591-4314	250' x 60' x 10'	100 T
1945-999-7899	300' x 80' x 13'	500 T
1945-573-5227	300' x 90' x 13'	100 T
1945-591-4313	427' x 90' x 15'	100 T

Note. Barges having 100 T pneumatic jacks are covered in TM 5-360. Those having 500 T pneumatic jacks are covered in TB 5-360-1.

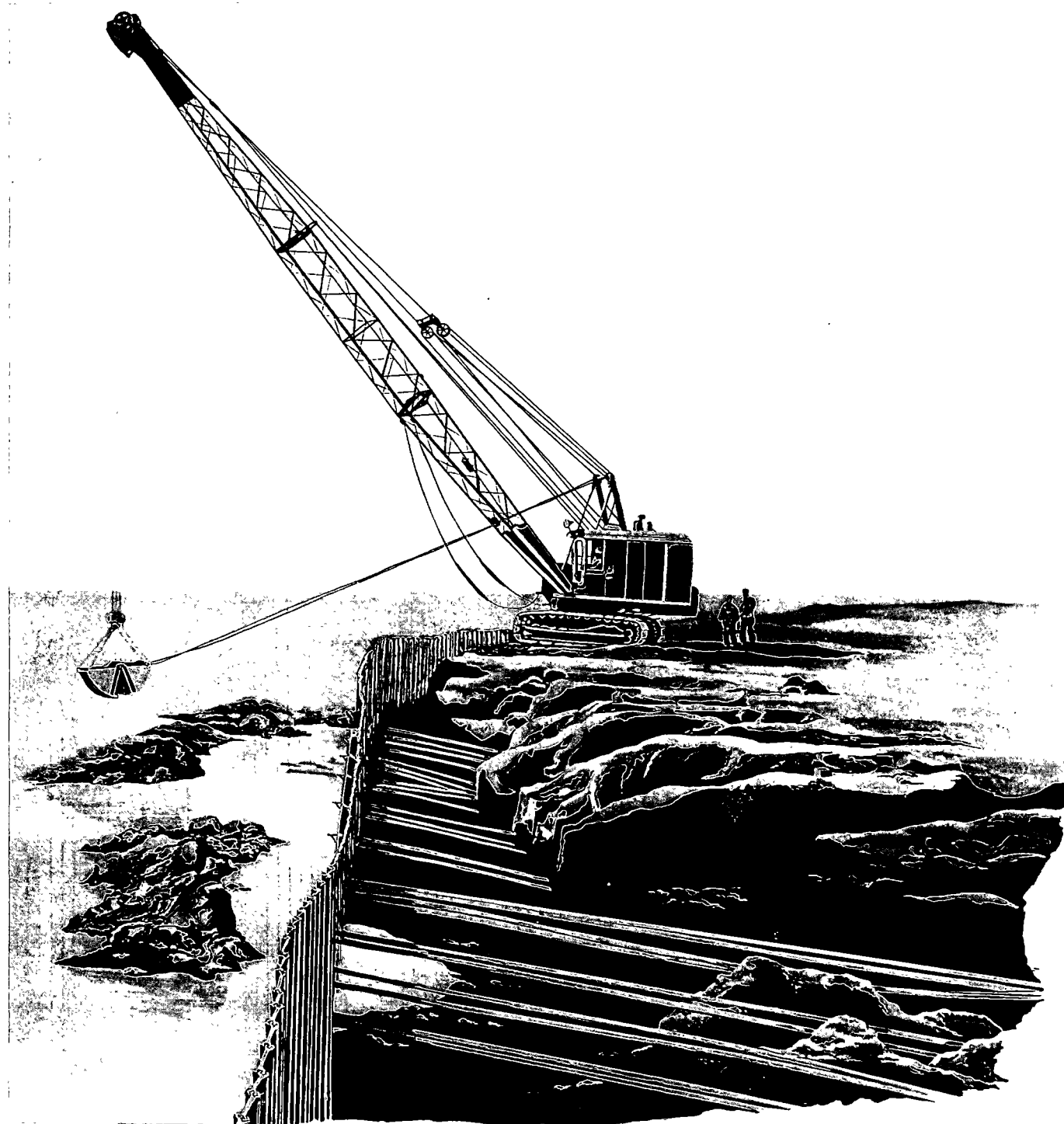


Figure 7-2. Construction of a sheet-pile bulkhead.



Figure 7-3. Construction of a timber pile wharf.

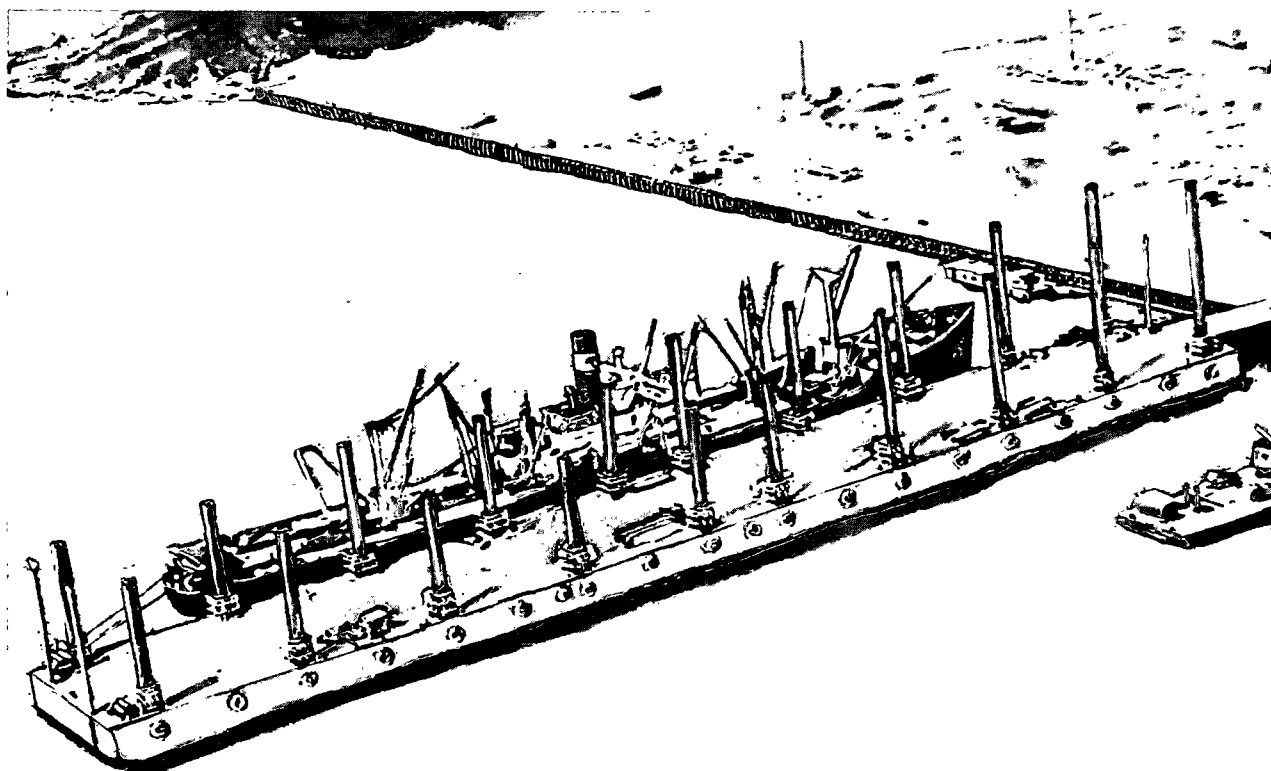


Figure 7-4. Finger pier of self-elevating barges.

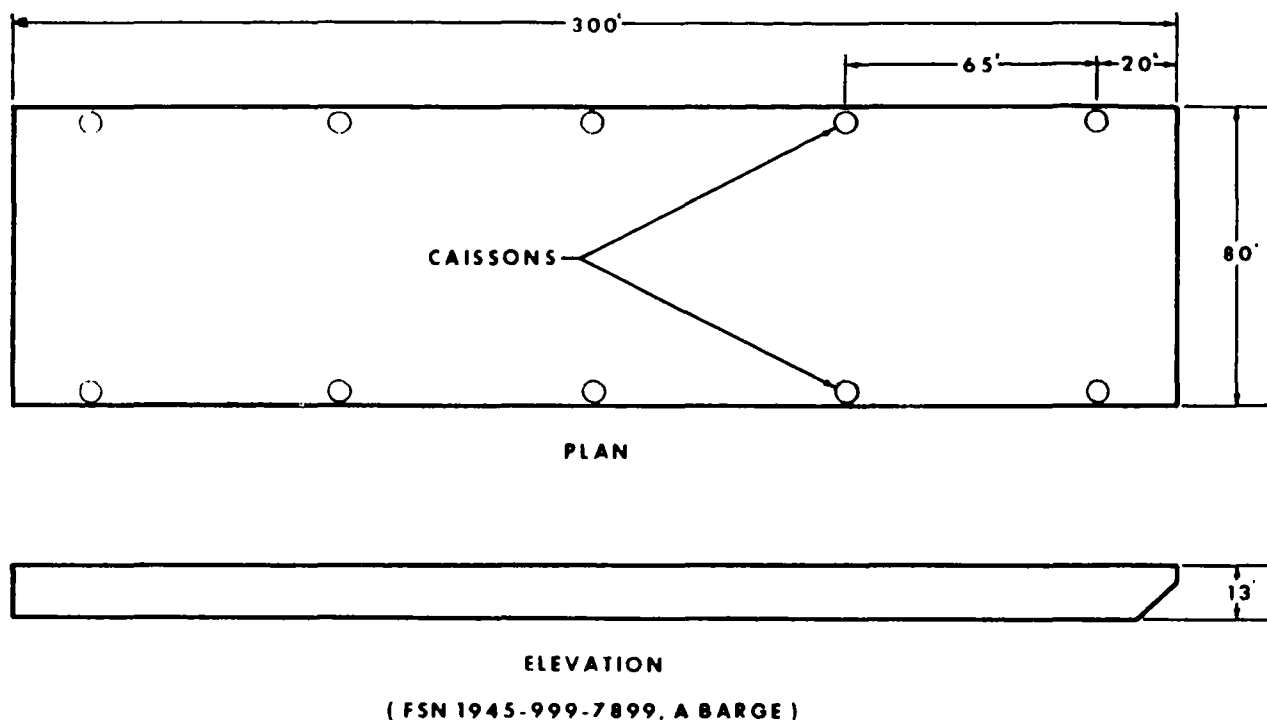


Figure 7-5. 300-foot barge unit.

Table 7-3. Types and Suitability of Soils

Types	Group symbols ¹	Suitability
Impenetrable surfaces	-----	Unacceptable
Organic soils	Pt, OH, OL	Unacceptable
Fine grained clays and silts wet (Mud).	MH, CH	Unacceptable
Fine grained clays and silts partly consolidated.	ML, MH, CL-CH, CL-CM	Marginal
Fine grained clays and silts dry.	ML, CL	Acceptable
Sand or sand with silt and clay.	SW, SP, SM, SC	Acceptable
Gravel or gravel with silt and clay.	GW, GP, GM, GC	Excellent

¹ Military Unified Soil Classification System.

Note. Table based on weight of barge loaded to capacity.

sand. Table 7-3 may be used for guidance in preliminary planning for site selection.

(4) Shore accessibility as well as onshore approaches are other important considerations in site selection.

7-6. Estimating Water-Terminal Capacity

The following example demonstrates the recommended procedure for estimating water-terminal capacity. For planning purposes, the average ship is considered to be 450 feet long and 60 feet wide with five hatches and an average discharge rate of 720 ST per 20 hour day. The average lighter is 100 feet by 35 feet with a dis-

charge rate of 180 ST per 20-hour day. The example is based upon the harbor chart in figure 7-6.

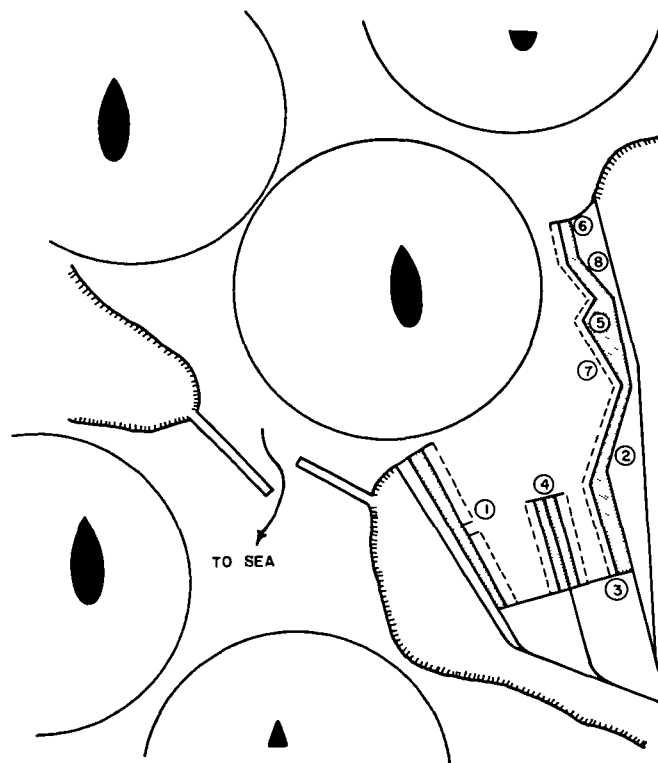


Figure 7-6. Harbor chart for terminal capacity estimation.

a. Wharf Facilities.

Wharf No.	Length		Width		Minimum depth alongside	
	Feet	Meters	Feet	Meters	Feet	Meters
1	1,060	323	80	24.4	32	9.8
2	490	150	60	18.3	30	9.2
3	580	177	90	17.4	30	9.2
4	535	163	100	30.5	34*	10.4*
5	125	38	54	16.5	8	2.4
6	295	90	60	18.3	15	4.6
7	450	137	75	22.9	22	6.7
8	210	64	60	18.3	16	4.9

*Each side.

b. Anchorage Areas.

(1) There is sufficient area inside the harbor to anchor three ships where they can be worked continuously.

(2) In good weather, two vessels can be anchored and worked outside the breakwater.

(3) Winds, swells, tides, and tidal currents present no unusual problems.

c. Discharge Tonnage.

(1) At deep draft wharfage.

Wharf No.	Victory ship berths	Discharge rate (ST per day)
1	2	$2 \times 720 = 1,440$
2	1	$1 \times 720 = 720$
3	1	$1 \times 720 = 720$
4	2	$2 \times 720 = 1,440$
Total		4,320

(2) At lighterage wharves.

Wharf No.	Lighter berths	Discharge rate (ST per day)
5	1	$1 \times 180 = 180$
6	3*	$3 \times 180 = 540$
7	4	$4 \times 180 = 720$
8	2	$2 \times 180 = 360$
Total		1,800

*Wharf No. 6 is only 295 feet long. Normally three ships require 300 feet. However, the 5-foot shortage will not affect operations appreciably and three lighters are docked here.

(3) *Alternate method.* If only the total of wharfage is known, this length in feet may be multiplied by 1.2 for alongside discharge and by 1.4 for lighterage discharge. The quantities thus obtained are conservative planning figures; they are expressed as long tons discharged per day.

d. *Rate of Discharge From Ships at Anchor to Lighters.* According to the chart, three ships can be anchored inside the breakwater, and two can be anchored and worked outside the breakwater in good weather. Therefore, in good weather, cargo can be discharged from ships to lighters at the rate of $(3+2) \times 720 = 3,600$ short tons per day.

e. Summary of Daily Terminal Capacity.

(1) Discharged alongside deepdraft wharves—4,320 short tons per day.

(2) Discharged from lighters to wharves—1,800 short tons per day.

(3) Transferred from ships to lighters—3,600 short tons per day.

(4) The maximum discharge per day is 1,800 short tons because lighter wharfage is the limiting factor. Therefore the total daily terminal capacity is 6,120 short tons: 4,320 short tons alongside; 1,800 short tons by lighter.

f. Personnel and Equipment Requirements.

Personnel and equipment requirements to maintain the above daily tonnage figure may be determined by dividing 6,120 short tons by 720 short tons (daily terminal service company discharge capability). Therefore, nine terminal service companies (TOE 55-117) or their equivalent in personnel and equipment and the necessary lighterage support will be required to maintain the discharge capacity of this terminal.

g. *Weather Considerations.* Advance study must be made to determine the probable effect of bad weather on the rate of discharge and other factors in water terminal capacity. Continuous records of daily discharge plotted against weather and surf conditions prove valuable in planning future discharge at the same and similar terminals.

7-7. Rehabilitation Considerations

a. *Reconstruction.* Port reconstruction generally is carried out in three phases.

(1) First phase.

(a) Subject to the provisions of the operation orders, normally the Navy carries out major clearing and salvage operations, and major dredging for channels and slips. In an area intended primarily for use as a naval base, Navy units continue construction of other facilities; but in areas for ground force use, Navy activities normally are limited to those necessary to get the waterways open and free from mines and similar hazards.

(b) The operation orders upon which the assault of a port area is based normally include a statement of the engineer missions in the port area, and of the arrangements for liaison between ground force and naval units.

(c) During the assault phase, engineer construction units reconnoiter harbor facilities and routes of communication, note the beach improvements and interim facilities to be expected

from shore party activities, and take any practicable action to restore to use any deep-draft or lighter wharfage which is accessible and is not heavily damaged. Possible utilization of vessels sunk alongside piers or wharves is considered during this phase, and naval units are consulted for advice and assistance in improvising wharf decks over their hulls.

(2) *Second phase.* Existing structures are rehabilitated or expedient methods are developed for handling cargo. These may include—

(a) A continuation of the work done in phase one by shore parties.

(b) Construction of floating wharf structures if Navy pontoon gear is available.

(c) Erection of self-elevating spud barge piers, if available.

(d) Repair of existing structures using expedient methods.

(3) *Third phase.*

(a) Repairable wharf structures are more permanently rehabilitated. TM 5-302, drawing numbers 15-01 through 15-05 and 15-24 through 15-26 give details of such rehabilitation.

(b) New unloading facilities are constructed. Plans for standard structures are contained in TM 5-302, drawing numbers 15-06, 15-07, 15-21, and 15-22.

(c) Work on highways, railroads and canals, and storage facilities outside the wharf area of the port are scheduled to keep pace with the development of berthing and unloading facilities at the water front.

b. Dredging. Since dredging is a slow operation, dredging harbors in a military operation should be avoided if possible. Likewise, because of the danger of damaging foundations, plans should not anticipate dredging in the close proximity of quay walls. Generally, demolition debris can be cleared in front of berthing sites by the use of dragline or clamshell cranes. If dredging in harbor areas is unavoidable, the information on table 7-4 may be used as a planning guide. TM 5-360 has more complete coverage on this subject.

c. Tanker Mooring Facilities. Considerable planning and technical reconnaissance is necessary for the selection of offshore tanker moorings. The anchor holding capacity of the sub-bottom is critical. Cargo ships whose anchors may slowly slip can simply raise them and reanchor

further ahead. The anchors of a multileg mooring system for tankers cannot slip since the ship must remain within a few feet (25 to 50) of a fixed point directly above the end of the submarine pipeline for periods of 20 to 24 hours. Otherwise the unloading hose between the tanker manifold and the pipeline will be torn apart or the pipeline broken off. Far from shore and at night gradual movement of the tanker due to anchor slippage usually goes unnoticed until it is too late to prevent damage and the loss of several thousand gallons of fuel and the creation of a highly explosive condition. In addition to determining the adequacy of the sub-bottom, consideration must be given to probable direction and intensity of storm winds, littoral or tidal current, coral heads, pilings, and submerged groins and former sea walls. Unless tugs will be available to assist the tanker in and out of the mooring, the moorings must be headed into the current so that it will assist the loaded tanker (low in the water) into the berth and provide for better initial steerage as the empty tanker (high in the water) retrieves its bow anchor and gets underway. A minimum maneuver area of $\frac{1}{2}$ mile radius should be provided around each tanker mooring unless assistance by tugs will be provided. Selection of the mooring site from shore will also be influenced by the amount of suitable pipe available and the profile of the bottom on which the submerged pipe will rest. Undue overbending and spanning of the pipeline must be avoided. Another influencing factor is the magnitude of the current near the bottom (1 to 2 feet) since a strong current can cause damaging vibration to an unsupported length of pipeline and lateral movement of the line unless additional anchoring of the pipeline is provided. Deep soft mud along the pipeline route should be avoided if possible since this makes periodic underwater inspection and any repair of the line difficult.

7-8. Effects of Natural Phenomena

Certain events of nature play an important role in harbor planning, construction, and rehabilitation. Of these, waves, tides, current and wind are the most significant.

a. Waves. Waves may be caused by wind, tides, and earthquakes, or artificially by ships, explosions, or other acts of man. The artificial waves are relatively unimportant. Of primary concern to the engineer is the force of the wave due to

Table 7-4. Dredging Equipment and Capabilities

1	2	3	4	5
Type of dredge	Hydraulic suction ¹	Dipper	Clamshell or orange peel	Seagoing hopper ²
Size -----	12"-28" pipe	2-16 cu yd	1-9 cu yd	700-5,000 cu yd
Operating personnel -----	Varies from 12-90 man crews, depending on size of dredge and number of shifts being worked.			
Operating characteristics and principle use.	Soft digging, river-channel dredging.	Clay, rock, or debris excavation.	Dredging in limited areas, caisson work, debris clearance.	Outer harbor work. Spoil area may be several miles away.
Maximum swells affecting operations.	3'/.9m	10'/3m	10'/3m	Designed for dredging in rough water.
Maximum dredging depth (feet/meters).	15'-65'/4.6m-19.8m	20'-50'/6m-15.2m	10'-60'/3m-18.2m	36'-60'/11m-18.2m
Average daily capacity ³ (cubic yards).	5,400 (12") 28,000 (28")	2,000 (2 cu yd) 9,000 (16 cu yd)	500 (1 cu yd) 3,000 (9 cu yd)	6,500 (700 cu yd) 10,000 (5,000 cu yd)

¹ The average distance which this type of dredge pumps to a spoil area is 300-900 meters. On the Fort Peck Dam, the 28" dredge pumped 3,500-9,500 meters.

² The 700-cubic yard "Hoffman Type" dredge was designed for use in World War II. It is especially useful in cutting a channel across a shoal at a harbor entrance. In a military operation, it is probable that all other dredging would be accomplished with local equipment or on-site expedients.

³ Dredges normally require 1 day per week shutdown for maintenance. These figures do not include maintenance delays but do include time consumed in moving the dredge along the cut area.

its height. One method of estimating wave energy is by the following formula:

$$E = 8LH^2$$

where:

E = energy in feet/pounds per linear foot of wave front.

L = length; distance from crest of one wave to crest of following wave.

H = height; distance from crest of wave to bottom of adjacent trough.

Wave pressures of 50 psi have been recorded, but these are maximum and rare.

b. Tides. Tides are the periodic rising and falling of large bodies of water due to the influence of the moon and sun. Tidal heights are measured from datum planes. The four datums are:

(1) Mean high water—average high water mark for 19-year period.

(2) Mean low water—average low water mark for 19-year period.

(3) Higher high water—higher of the two high waters of the diurnal tidal day.

(4) Lower low water—lower of the two low waters of the diurnal tidal day.

c. Current. Current is the movement of water

horizontally. Tides cause periodic and reversing currents. Wind produces current and waves. When the waves strike the shore at an angle, the returning water forms a current parallel to the shore. This is known as a littoral current and it may erode or deposit eroded sand along its path. Current in streams and rivers varies from season to season and in the stream itself, being less in shallow water and along the bottom, and highest in the center of the deepest part. Stream currents may also erode or deposit sand, and this may be an important consideration in port or harbor construction.

d. Wind. Wind is the movement of air from one place to another caused by changes of temperature. It exerts pressure on objects in its path in accordance with the following formula:

$$P = CV^2$$

where:

P = pressure (lb/ft²)

V = velocity (miles/hr)

C = constant .00256

Wind pressure is also a function of the size and shape of a structure, and may vary from 1.3 to 1.6, 1.3 being used for low structures such as vessels and docks. The adjusted equation then is:

$$P = 1.3CV^2$$

Section II. NAVY PONTONS

7-9. Description

There are four types of steel pontons designed to be assembled into floating structures of various sizes and shapes. They are described below and illustrated in figure 7-7.

a. The T6B or Rectangular Ponton. The T6B is 5 feet 1/2 inch by 7 feet in deck area and 5 feet 1/2 inch deep. The side, end, deck, and bilge plating is 3/16 inch thick. The deck is of checkered plate. Four 2-inch-diameter plugged holes are provided near the corners on one side plate for air, sea cocks, drain, or siphon connection. The ponton weighs 2,000 pounds and has a volume of 175 cubic feet.

b. The T7A or Curved-Bilge Ponton. The T7A has the same depth as the T6B, but it has a curved bilge and its deck is 7 feet square. The side, deck, and end plates are 3/16 inch thick; the bilge plating is 3/8 inch thick. The deck is of checkered plate. Four 2-inch-diameter plugged holes are provided in the side plate (the plate opposite the curved end). It is used for the curved bow and stern of barges. It weighs 2,800 pounds and has a volume of 189 cubic feet.

c. The T8 or Sloped-Deck Ponton. The T8 is 5 feet 2 3/8 inches by 7 feet in deck area and is inclined. The depth is 4 feet 11 3/8 inches at one end and 3 feet 6 inches at the other. The bottom is horizontal. All the plating is 3/16 inch thick. The deck is checkered. There are two 2-inch-diameter plugged holes in the deep end.

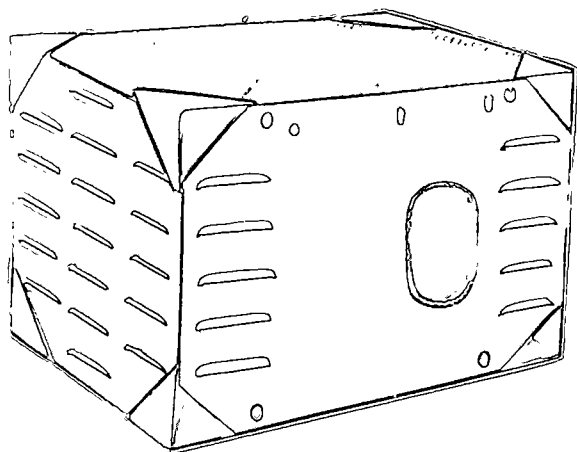
d. The T11 or Ramp-End Ponton. The T11 has the same inclined-deck area as the T8. The offshore end is 3 feet 6 inches deep; the inshore end 1 foot. The bottom is horizontal for the first 1 foot 8 inches, and then pitches upward. The deck is 3/16-inch checkered steel plate, the side and end plates 3/16 inch plain, the bilge plating 3/8 inch plain. The front vertical edges should be protected by welding on fenders consisting of half-sections of 6-inch steel pipe. There are two 2-inch-diameter plugged holes in the deep end.

e. Assembly Angles. The three standard sizes of steel assembly angles are 6 by 6 by 3/8 inches, 6 by 6 by 1/2 inches, and 8 by 8 by 1/2 inches. In assembling pontons, the size of angle used depends on the nature and size of the assembly and

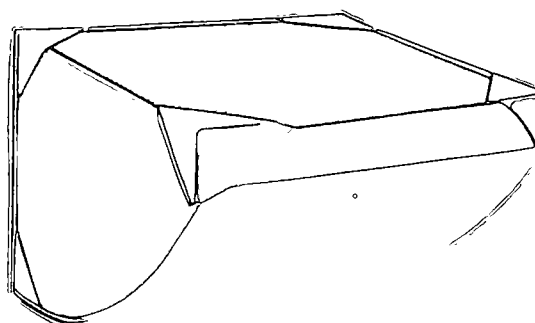
the rigidity required. The angles are fitted with wedge bars, to which the pontons are attached by the jewelry, and with $\frac{1}{8}$ -turn breech-plug-slice end couplings for great lengths of assembly. Assembly angles can be altered by cutting and welding but cannot be improvised in the field be-

cause of the accuracy required in the spacing of the wedge bars.

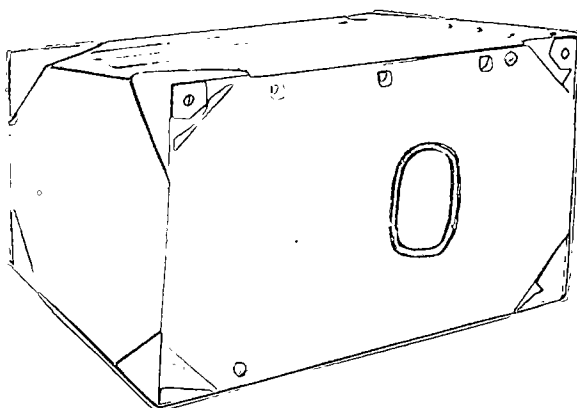
f. Sets. The pontons, assembly angles, jewelry, and other accessories and special parts are made up and shipped in standard sets.



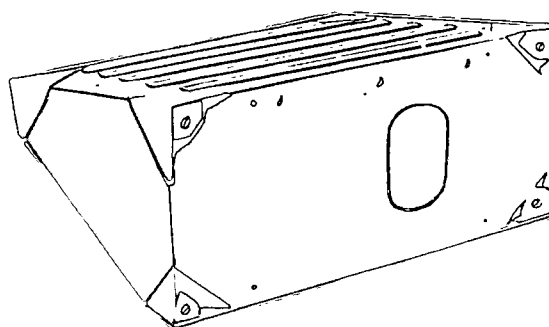
T6B, RECTANGULAR PONTON.



T7A, CURVED-BILGE PONTON.



T8, SLOPED-DECK PONTON.



T11, RAMP-END PONTON.

Figure 7-7. U.S. Navy pontons.

7-10. Ponton Assemblies

The standard sets of pontoons and accessories can be assembled into floating units of various types and sizes. These include barges, floating bridges, causeways, floating wharves, drydocks, and other structures.

7-11. Barges

a. *Use.* Ponton barges can be used in a variety of situations as substitutes for ordinary rigid barges. They can also be equipped for use as cranes, piledrivers, drill rigs, and other special-purpose floating plants. If equipped with special inboard or outboard propulsion units, they can be used for icebreakers or tugboats.

b. *Assembling.* Normally, a string of pontoons of a length depending on the desired length of the barge is first assembled and launched. T7A pontoons are used for the ends and T6B for the rest of the string (fig 7-8). Other strings are similarly assembled and launched, and the strings are then connected side by side to give a

barge of the desired width. Assembly is by link-and-pin connection at the top angles and by tie rods near the bottom, as shown in figure 7-9. Installation of A13 deck-closure channels (8-inch ship channel, 18.7 pounds, 5 feet 10 $\frac{3}{4}$ inches long) as shown in figure 7-10 completes the assembly for standard purposes. Figure 7-10 also shows the method of determining the precise length of a string. Accessories to permit other types of closure and also cleats, chocks, bollards, bits, etc., are available in the standard sets. These ponton strings must be assembled in protected waters. Assembly and launching of the strings is best accomplished in relatively flat areas having a sea wall 4 to 5 feet above the water level. Assembly time for barges will average 3 to 8 hours per ponton depending upon the state of training of the troop unit. These ponton barges are highly vulnerable to breakup unless the pontoons are welded to the structural members. Their use should be restricted to protected water if possible.

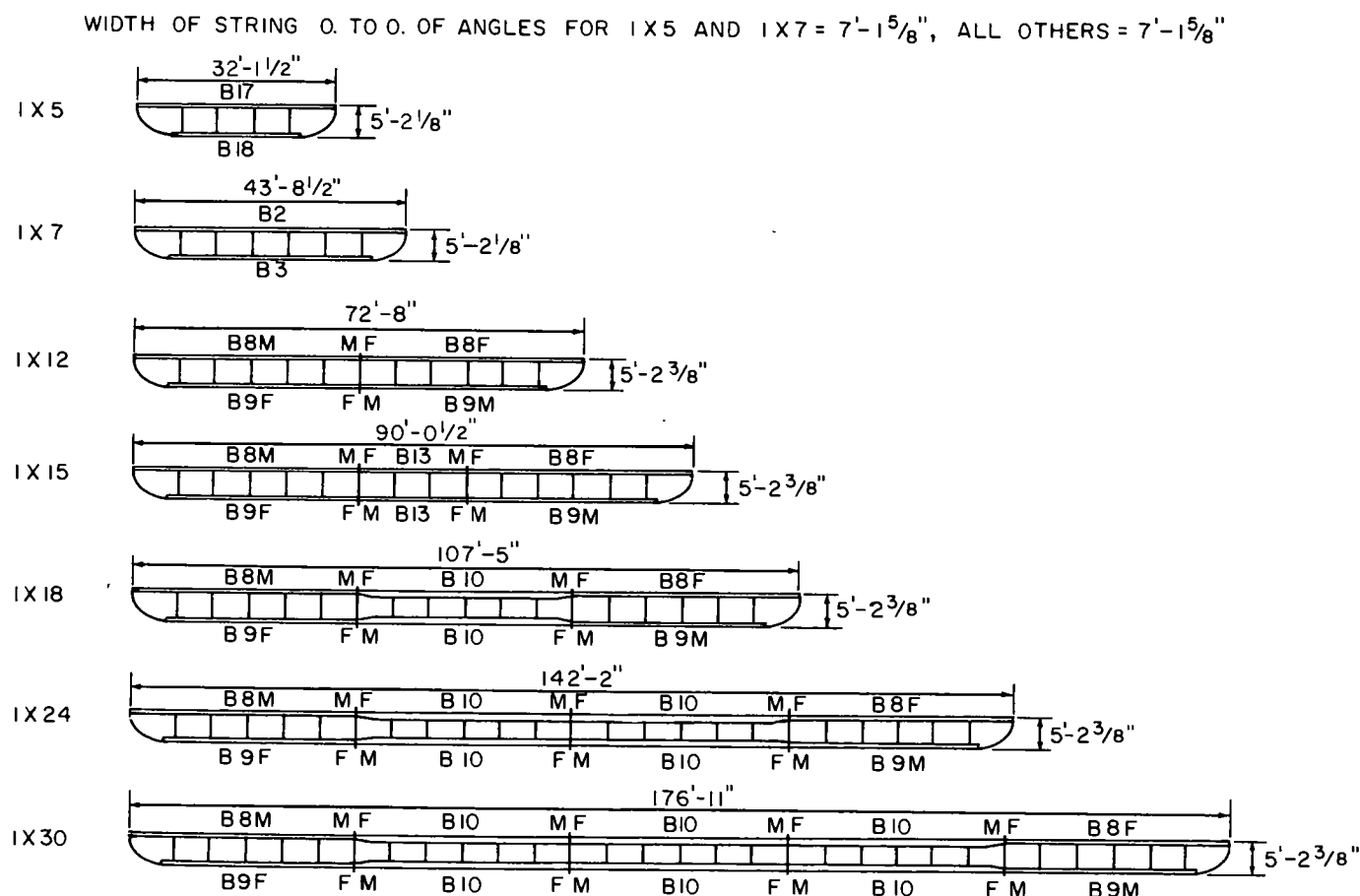


Figure 7-8. Side elevation of barge strings.

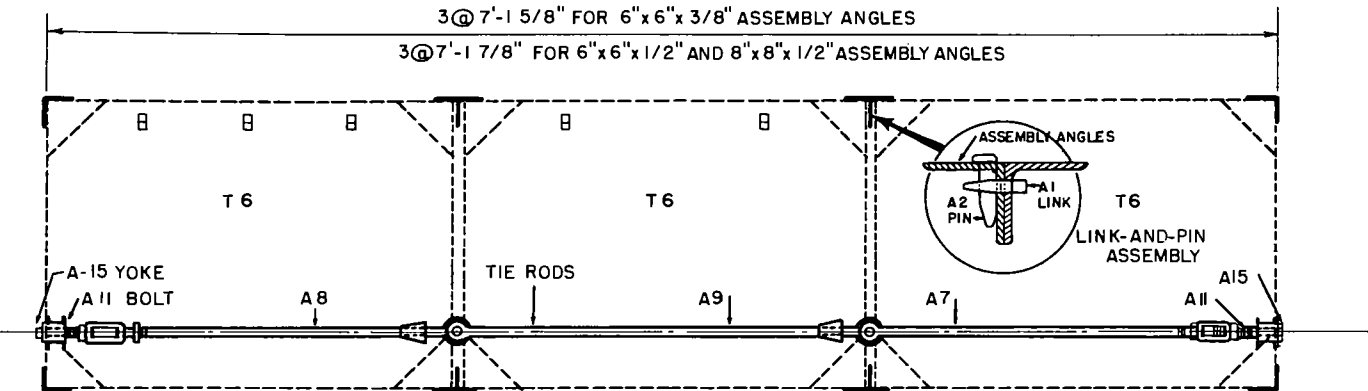
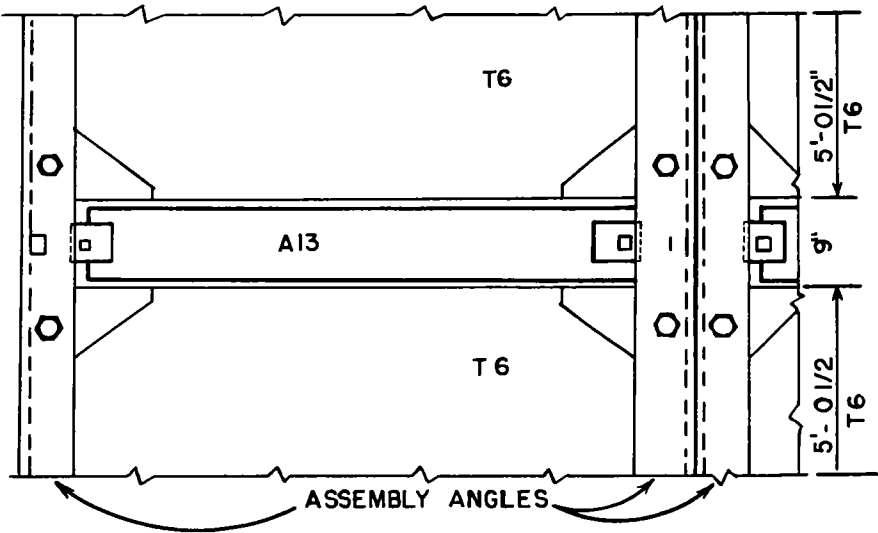


Figure 7-9. Lateral assembly of barge strings.



NOTE:
To determine length of any string, add 9" for each longitudinal space between pontons.
e.g. length of 6 x 18 barge:
2 Pontons T 7 @ 7'-0" = 14'-0"
16 Pontons T 6 @ 5'-0 1/2" = 80'-8"
17 Spaces @ 9" = 12'-9"
Total length 107'-5"

Figure 7-10. Deck-closure channels; determining length of string.

c. *Buoyancy and Capacity.* Ponton barges up to 6 by 18, about 43 feet by 107 feet and rated at 250 tons with 48-inch draft, are designed to carry a load at the center point heavy enough to bring the deck awash. For longer barges, the maximum load the barge can float must be distributed over at least the center six pontons of a 24-long barge and at least the center of 12 pontons of a 30-long floating structure. Table 7-5 shows the load capacities, in tons, of certain standard barge assemblies.

7-12. Bridges

a. *Standard Bridge Units.* The term "standard bridge unit" is normally applied by the Navy to an assembly of pontons used to connect a floating ponton wharf to the shore. Such units may

also be used to bridge a waterway. The standard units are:

- (1) The 2-by-12 bridge unit, -composed of two strings each containing 10 intermediate T6B and two end T7A pontons.
- (2) The 4-by-18 bridge unit, composed of four strings each containing 16 intermediate T6B and two end T7A pontons.

Table 7-5. Standard Barge Assemblies

Number of pontons wide x long	Capacity (tons)	Nominal width and length (feet)	Draft	
			Light (inches)	Loaded (inches)
3 x 7	50	21 x 43	20	48
4 x 12	100	28 x 72	20	44
5 x 12	125	35 x 72	20	48
6 x 18	250	43 x 107	20	48
6 x 30	500	43 x 175	20	48

b. *Bridge Strings.* Strings of pontoons, known as bridge strains, are also used to bridge a waterway. Normally they are made of T6B pontoons. Figure 7-11 shows the side elevations of such bridge strings. Any desired width can be attained by assembling strings laterally.

c. *Bridging a Waterway.* The strings or units used for this purpose are assembled, launched, and floated into position. The bridge must be anchored and the approaches prepared, as in the

case of Army ponton equipment. Anchors are not provided with the standard sets. T8 and T11 pontoons may be used at the shore ends. To adjust the length of unit assemblies to the width of the river, strings or units may be lapped in mid-stream, care being taken to make the lap long enough for vehicles to negotiate (figs 7-12 and 7-13). Acting as a beam, a 2-by-12 ponton bridge, supported only at each end, will carry a 40-ton vehicle at its center.

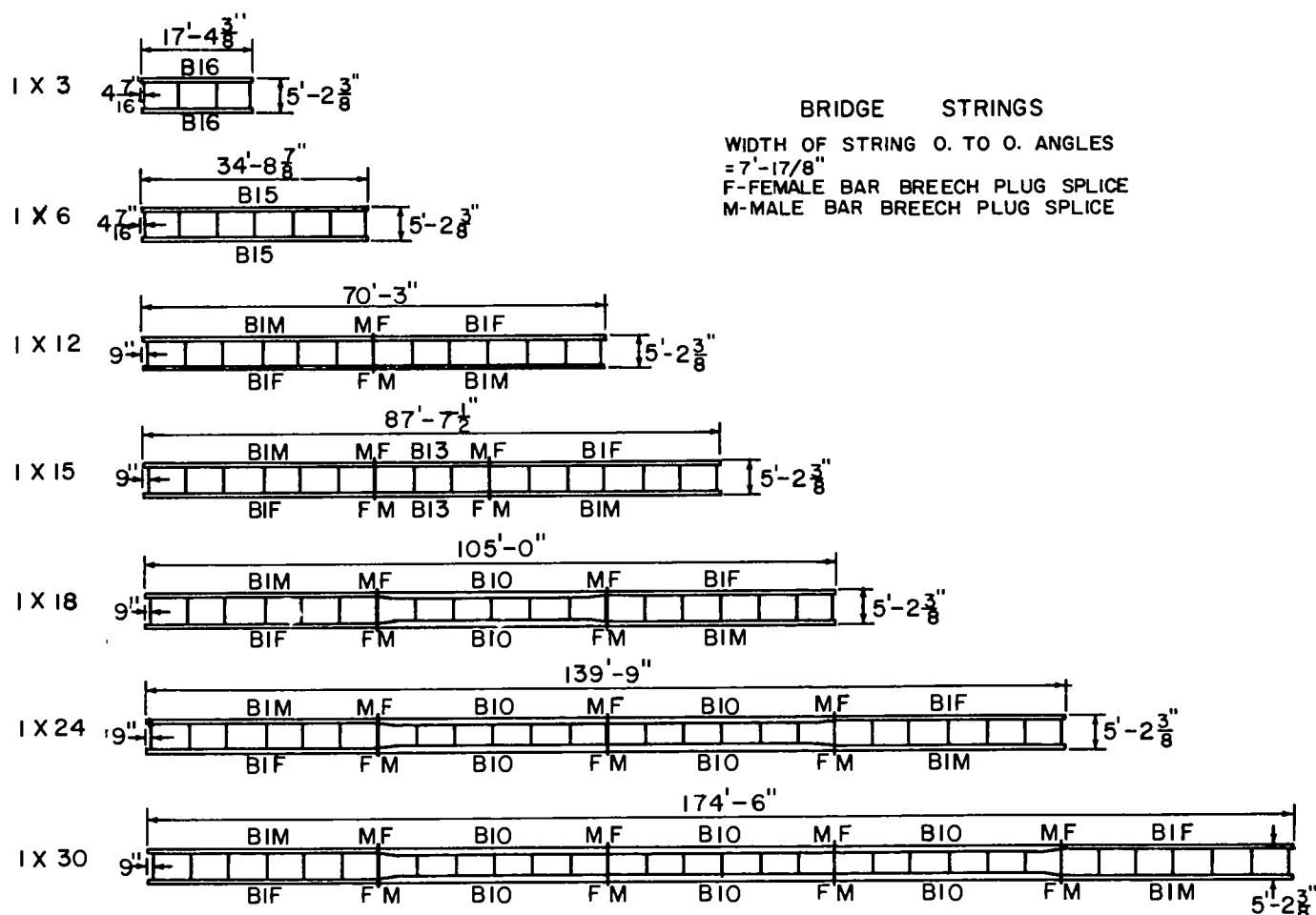


Figure 7-11. Side elevation of bridge strings.

7-13. Standard Causeway

This assembly, made like a 2-by-30 barge, about 14 feet by 175 feet, is side-carried on LST's and launched to permit dry landings on flat beaches. The causeway units can be assembled later for other bridge, wharf, or barge purposes. End pontons are T11.

7-14. Wharves

a. The standard sizes are 5-by-12, (about 36 by 70 feet), and 7-by-60, (about 50 feet by 350 feet). All pontons are T6B.

b. Wharves six or more pontons wide and 72 pontons long, about 43 feet wide by 420 feet

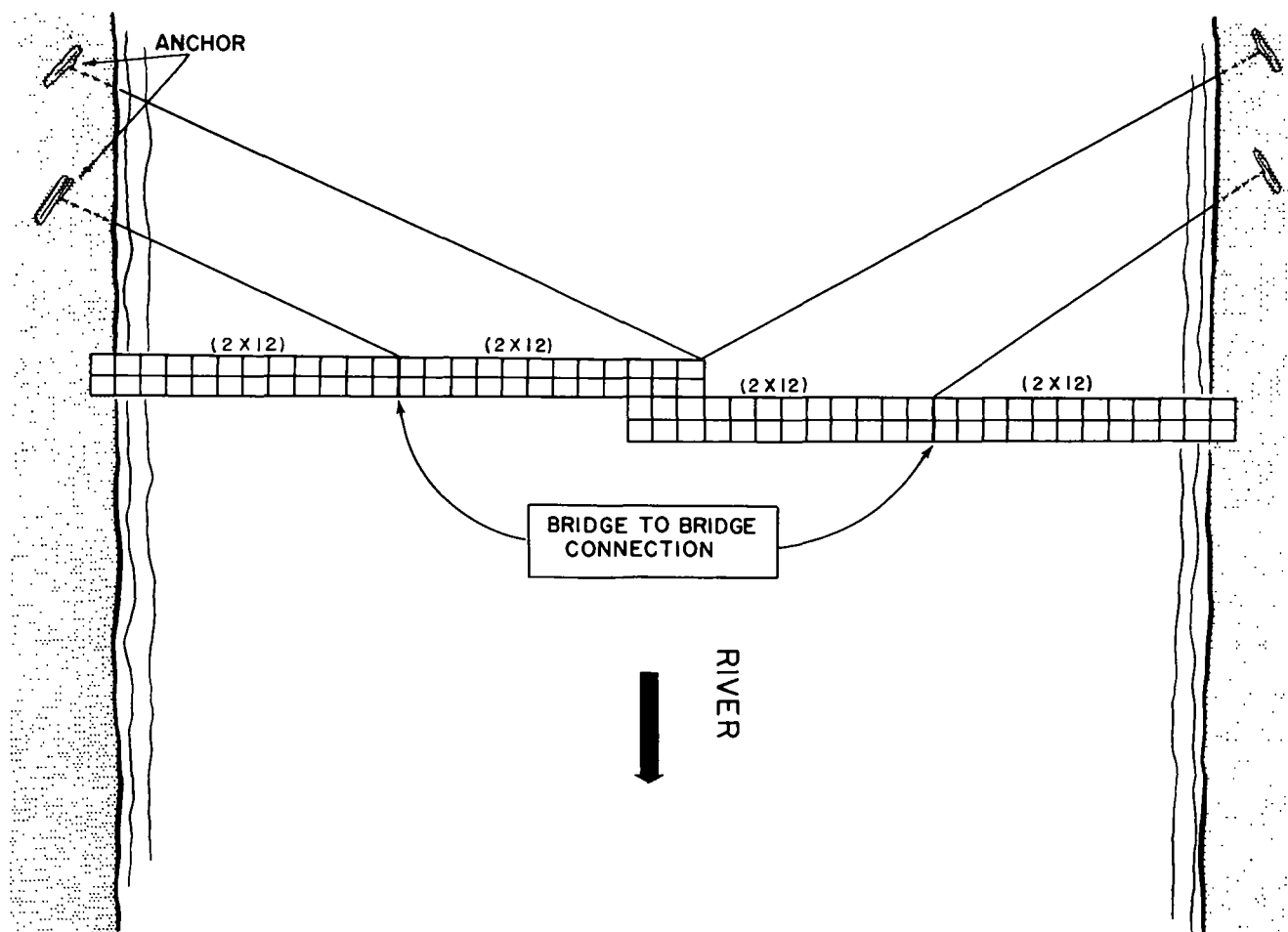


Figure 7-12. A bridge made of standard 2-by-12 units, lapped in midstream.

long, have been used satisfactorily for unloading cargo ships of Victory and Liberty type (fig 7-14). To have adequate depth alongside, they must normally be moored offshore and fitted with bridge approaches. Three approaches, each four pontons wide, are usually adequate.

c. In protected water with depths and bottom materials suitable for pile dolphins, there is no structural limitation on the size of either marginal or finger-pier floating wharves. Satisfactory moorings for such wharves have been developed by omitting one T6B ponton at each corner and at intervals along the face and driving a pile cluster in each of the openings thus provided. The pile clusters also serve as ship moorings and as fenders to hold hulls away from the wharf.

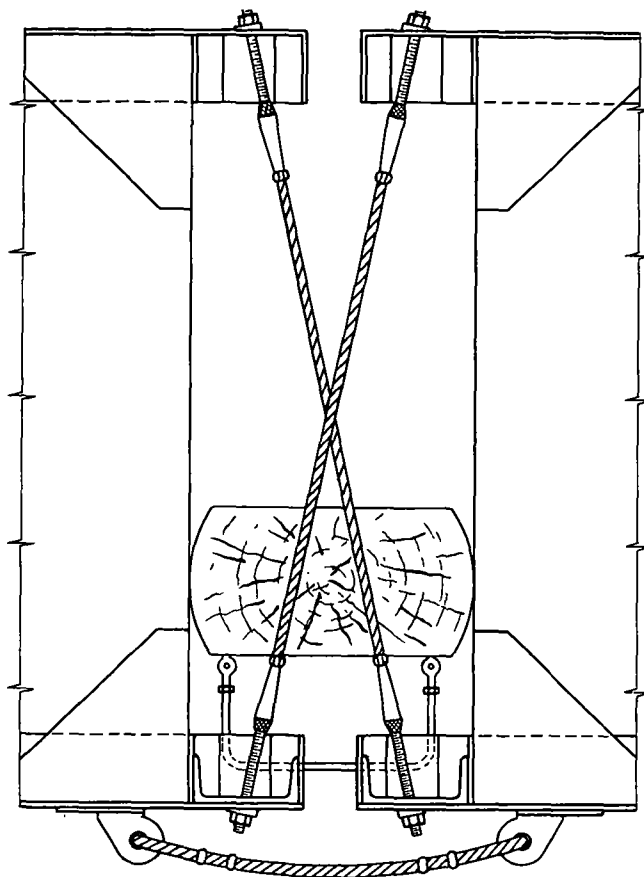


Figure 7-13. Bridge-to-bridge connection.

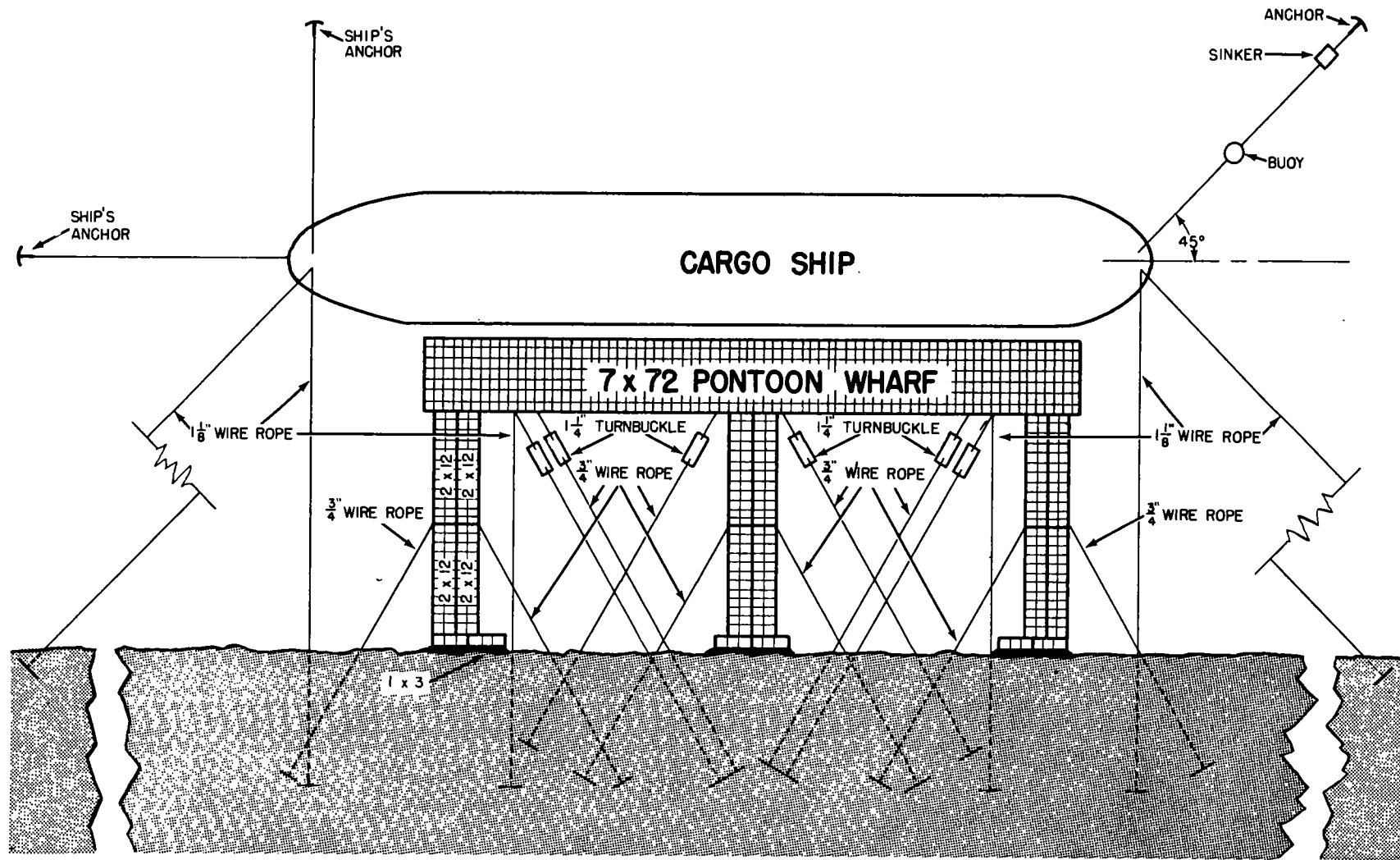


Figure 7-14. A 7-by-72 floating wharf, showing typical moorings.

Section III. SHIPS AND AMPHIBIANS

7-15. Definition of Ship-Loading Terms

a. Units of Weight.

(1) Short ton (STON)—2,000 pounds. Used by U.S. ships in domestic trade.

(2) Long ton (LTON)—2,240 pounds. Used by U.S. ships in foreign trade.

(3) Metric ton—2,205 pounds. Used by foreign shipping.

b. Units of Volume.

(1) Measurement ton (MTON)—40 cubic feet. Used by U.S. ships in foreign trade.

(2) Register ton—100 cubic feet. (This tonnage is used for working out a basis to collect entry fees for the vessel and has no direct bearing on the cargo-carrying capacity of the vessel.)

c. Units of Distance and Speed.

(1) Distance—nautical mile = 6,076 feet.

(2) Speed—knot = 1 nautical mile per hour.

d. Gross Tonnage. Gross tonnage (gross register tonnage) is the entire internal cubic capacity of a ship expressed in register tons of 100 cubic feet each.

e. Net Tonnage. Net tonnage (net register tonnage) of a ship represents the cargo and passenger-earning spaces which remain after deduction from the gross tonnage of space for the crew, powerplant, fuel, and operation of the vessel. Net tonnage is expressed in tons of 100 cubic feet each.

f. Deadweight Tonnage. Deadweight tonnage is the carrying capacity of a ship expressed in long tons and represents the difference between

displacement loaded to maximum draft allowed by law and displacement light.

g. Displacement Tonnage Light. Displacement tonnage light is the weight of a ship in long tons and excludes the weight of cargo, passengers, fuel, water, stores, dunnage, and such other items necessary for use on a voyage.

h. Displacement Tonnage Loaded. Displacement tonnage loaded is the weight of a ship in long tons and includes the weight of cargo, passengers, fuel, water, stores, and such other items necessary for use on a voyage.

i. Cargo Deadweight Tonnage. Cargo deadweight tonnage is the weight-lifting capacity of a ship in long tons remaining after deducting from the deadweight tonnage the weight of fuel, water, stores, dunnage, and such other items as may be necessary for a voyage.

7-16. Maritime Administration Vessel Classification System

a. Method. The classification system established by the United States Maritime Administration is based upon three groups of letters and numbers. The first group (prefix) indicates the type of vessel, such as cargo or passenger, and its approximate size. The second group (intermediate) indicates the type of machinery, number of screws, and passenger accommodation. The third group (suffix) indicates the particular design of the type of vessel and modifications. For example: C2-S-AJ1 describes a cargo ship between 400 and 450 feet long (C2); single screw, steam machinery (S), and the AJ design (AJ), in its original version (1). Table 7-6 gives the prefix designations for most common commercial vessels.

Table 7-6. Prefix Designations

(1) Other than emergency and Victory types.

Single letter	Class of vessel	Length designation (load waterline in feet)						
		1	2	3	4	5	6	7
C	Cargo, unlimited service, under 100 passengers.	Under 400	400-450	450-500	500-550			
P	Passenger, unlimited service, over 100 passengers.	Under 500	500-600	600-700	700-800	800-900	900-1,000	Over 1,000
B	Barge	Under 100	100-150	150-200	200-250	250-300		
L	Great Lakes tankers (ore, grain)	Under 400	400-450	450-500	500-550	550-600	600-650	
N	Coastwise cargo	Under 200	200-250	250-300	300-350	350-400	400-450	450-500

Table 7-6. Prefix Designations—Continued

Single letter	Class of vessel	Length designation (load waterline in feet)						
		1	2	3	4	5	6	7
R	Refrigerator	Under 400	400-450	450-500	500-550			
S	Special	Under 200	200-300	300-400	400-500	500-600	600-700	
T	Tanker	Under 450	450-500	500-550				
V	Towing vessels	Under 50	50-100	100-150	150-200			
Z	Conversion*							

*For conversions of established types, "Z" is prefixed to original designation with new final number in some cases.

(2) *Emergency and Victory types.*

Double letter	Class of vessel	Length designation (load waterline in feet)			
		1	2	3	4
EC	Emergency cargo (Liberty ship)	Under 400	400-450	450-500	500-550
ET	Emergency tanker	450			
VC	Victory cargo	Under 400	400-450	450-500	500-550

b. *Intermediate Letter or Group.*

Type of machinery	Type of propeller	Under 12 passengers	Over 12 passengers
Steam	Single	S	S1
Motor	Single	M	M1
Turboelectric	Single	SE	SE1
Diesel-electric	Single	ME	ME1
Gas turbine	Single	G	G1
Gas turboelectric	Single	GE	GE1
Steam	Twin	ST	S2
Motor	Twin	MT	M2
Turboelectric	Twin	SET	SE2
Diesel-electric	Twin	MET	ME2
Gas turbine	Twin	GT	G2
Gas turboelectric	Twin	GET	GE2
Steam	Stern wheel	SW	SO
Motor	Stern wheel	MW	MO

there is only one letter, this indicates that the design originated earlier than one having two letters. The figure following the letter or letters in the suffix indicates that it is either the original design of that particular alphabetical designation or a modification thereof. The original design is always numbered 1.

7-17. Characteristics of Commercial Ships

Tables 7-7 and 7-8 give carrying capacities, dimensions, uses, and other characteristics of most common commercial ships. There is such a large difference in the cubic-carrying capacity of vessels of the same type, because of various alterations and special fittings, that the cubic feet and tonnage figures shown in the following tables are, in most instances, minimum and apply to one type of the designated vessel only.

Table 7-7. Tonnage and Description, Commercial Vessels

	1	2	3
	Type	Deadweight tonnage	Remarks
2	B7	5,700	Concrete hull, cargo barge, nonpropelled.
3	C1-A	7,400	Designed for general cargo in world trade; steam turbine and motor-propelled (two modifications).
4	C1-B	9,100	Designed for general cargo in world trade; steam turbine and motor-propelled (three modifications).
5	C1-M	5,000	Designed for general cargo; motor-propelled.
6	C1-S	5,000	Concrete ship designed for cargo purposes; steam-reciprocating-engine propelled.
7	C2	9,300	Designed for general cargo in world trade; majority steam-turbine propelled (several modified types). Modified types were used mostly as hospital ships in World War II.

Table 7-7. Tonnage and Description, Commercial Vessels—Continued

1	2	3
Type	Deadweight tonnage	Remarks
8 C3	9,900	Combination passenger and cargo ship; majority steam-turbine propelled (several modified types).
9 C3-S	12,300	Designed for cargo; steam-turbine propelled.
10 C4	15,000	Designed for cargo; steam-turbine propelled (two modifications).
11 C4-S-1a	12,900	Mariner class vessel. Developed by Maritime Administration in cooperation with the Department of Defense to provide modern high-speed commercial-type vessels which can readily be converted for wartime shipping.
12 EC2	10,800	Liberty-type designed for general cargo; steam-reciprocating-engine propelled. Several modified types, prefixed by the symbol Z, were designed as tank carriers and later modified as plane carriers.
13 L6	15,700	Specially designed for bulk ore, coal, or grain trade on the Great Lakes; steam-reciprocating-engine propelled.
14 N3	2,800	Cargo carrier designed for coastal trade; steam-reciprocating-engine propelled.
15 P1	1,900	Specially designed passenger-type vessel; steam-turbine propelled.
16 P2	10,000-12,000	Designed to carry troops. Two types, one turbine-electric propelled, one steam-turbine propelled.
17 T1	1,500-4,200	Designed for tanker service in coastal and inland waters; diesel-propelled (four modifications).
18 T2	16,000	Designed to carry bulk oil in world trade; turbo-electric propelled (four modifications).
19 T3	16,500	Designed to carry bulk oil in world trade; steam-turbine propelled (six modifications).
20 V4	800	Large diesel-powered oceangoing tug.
21 VC2	10,200	Victory-type designed to carry cargo in world trade. Four types: one has 6,000 HP engine; three have 8,500 HP engines. Three are steam-turbine propelled; one diesel-propelled.

Table 7-8. Characteristics of Commercial Cargo Ships

a. Physical characteristics.

1	2	3	4	5	6	7
Vessel	Gross register tonnage	Overall length (ft)-(m)	Beam (ft)	Sustained speed (knots)	Cruising range (nautical mile)	Summer draft (ft)-(m)
2 Liberty	7,100	442-135	57	11.0	¹ 9,000	28-8.5
3 Victory	7,600	455-139	62	15.5	23,000	29-8.8
4 C1-B Cargo	6,700	418-127	60	14.0	24,000	28-8.5
5 C2 Cargo	6,181	459-140	63	15.0	16,000	26-7.9
6 C3 Cargo	7,900	492-150	70	16.5	11,700	29-8.8
7 C4 Cargo	10,780	520-158	71	17.0	9,000	33-10.0
8 FS Freighter ²	560	176-54	32	12.0	4,000	12-3.6
9 C1-M-AV1 Freighter	3,805	339-103	50	11.0	25,000	21-6.4
10 T2-SE Tanker	10,200	524-160	68	14.5	12,600	30-9.1
11 ZET 1 Tanker ³	7,000	442-135	57	11.0	17,000	28-8.5
12 C4 Mariner	9,200	564-172	76	20.0	23,000	30-9.1

¹ Cruising range can be increased to 18,000 miles if deep tanks are used for fuel oil. See footnote 2 in c below.² FS type (freight service ship) is the 176-foot vessel built for the Army. It is an oceangoing vessel but, because of its small capacity, is used principally as an interisland carrier.³ Converted Liberty.

b. Hold, Hatch, and Boom Data.

1	2	3	4	5	6
Vessel	Cargo holds (number)	Boom capacity (LTON)	Booms (number)	Capacity heavy lift rigs (LTON)	Hatches with heavy lift booms (number)
2 Liberty	5	5	12	¹ 50-15	2-4
3 Victory	5	5	16	¹ 50-30	¹ 3-4
4 C1-B Cargo	5	5	15	30	2
5 C2 Cargo	5	5	17	50	3
6 C3 Cargo	5	5-10	21	30	5

Table 7-8. Characteristics of Commercial Cargo Ships—Continued

1	2	3	4	5	6
Vessel	Cargo holds (number)	Boom capacity (LTON)	Booms (number)	Capacity Heavy Lift rigs (LTON)	Watches with heavy lift booms (number)
7 C4 Cargo	7	5	24	50	4-5
8 FS Freighter ²	2	5	5	15	2
9 C1-M-AV1 Freighter	4	³ 3-5	12	30	2-3
10 C4 Mariner	7	5-10	26	60	4-6

¹ Some Libertys have a 30-ton boom at No. 2 hatch and a 15-ton boom at No. 4 hatch. Other Liberty ships have a 50-ton boom at No. 2 hatch and a 30-ton boom at No. 4 hatch. All Victorys have a 30-ton boom at No. 4 hatch.

² FS type (freight type ship) is the 176-foot vessel built for the Army. It is an oceangoing vessel but, because of its small capacity, is used principally as an interisland carrier.

³ Two 3-ton booms (No. 4 hatch) and ten 5-ton booms.

c. Vessel capacities.

1	2	3	4	5	6	7
Vessel	Deadweight (LTON)	MTON ^{1,2}	Bale cubic capacity (cu ft) ^{1,2}	Grain cubic capacity (cu ft) ¹	Refrg cargo (cu ft)	Liquid cargo (bbl)
2 Liberty	10,800	11,886	475,444	563,257		
3 Victory	10,800	11,413	456,525	528,325		
4 C1-B Cargo	9,100	11,300	452,000	508,000		
5 C2 Cargo	9,250	11,823	472,935	548,560		
6 C3 Cargo	12,300	18,425	736,980	815,470	³ 45,000	
7 C4 Cargo	14,863	17,790	672,240	727,430	⁴ 32,375	
8 FS Freighter	470	483	19,320	21,462		
9 C1-M-AV1	5,032	5,699	227,930	250,000	9,830	4,000
10 T2-SE Tanker	16,583	381	15,230			141,000
11 ZET-1 Tanker ⁵	10,800					65,000
12 Supertanker ⁶	25,000					165,000
13 C4 Mariner	12,900	18,418	736,723	837,305	30,254	

¹ On-deck space or lost space in stowage not included.

² Does not include capacity of deep tanks of which the Liberty-type ship has three. Deep tanks No. 1 and No. 2, with approximately 16,000 cubic feet of capacity, may be used for dry or liquid cargoes if not in use for vessel voyage requirements. No. 3 deep tank is rigged for either fuel oil or bulk cargo liquids. A 5,000-barrel (703 LTON) payload can be shipped in this tank if the contemplated voyage is to be short enough that No. 3 tank will not be needed for fuel oil.

³ Standard C3 has no refrigerated cargo capacity; figure given is for C3 passenger and cargo type.

⁴ Standard C4 has no refrigerated cargo capacity; figures given are for C4-S-A4 type.

⁵ Modified Liberty.

⁶ Supertankers are those tankers of over 25,000 DWT, which run up to 100,000 DWT or higher.

7-18. Navy Ship and Service Craft Designators

a. Special Instructions.

(1) The arrangement within categories and subcategories is alphabetical by symbol.

(2) Letter prefixes are used in conjunction with classification symbols as follows:

E—To indicate a prototype ship or craft that is in an experimental or developmental status.

T—To indicate that a ship is assigned to MSTS (Military Sea Transportation Service).

F—To indicate that a ship is being constructed for a foreign government.

(3) The letter "N" when used as the last letter of a ship classification symbol denotes nuclear propulsion. When used as the last letter of a service craft classification symbol, the letter "N" indicates a non-self-propelled version of a similar self-propelled service craft.

(4) Parentheses are not used to separate any letters in classification symbols.

b. Combat Ships.

(1) Warships.

Battleship BB

Cruisers:

Heavy Cruiser	CA
Guided Missile Cruiser	CG
Guided Missile Cruiser (nuclear propulsion)	CGN
Light Cruiser	CL
Guided Missile Light Cruiser	CLG
Command Ship	CC
Aircraft Carriers:	
Attack Aircraft Carrier	CVA
Attack Aircraft Carrier (nuclear propulsion)	CVAN
ASW Support Aircraft Carrier	CVS
Training Aircraft Carrier	CVT
Destroyers:	
Destroyer	DD
Guided Missile Destroyer	DDG
Frigate	DL
Guided Missile Frigate	DLG
Guided Missile Frigate (nuclear propulsion)	DLGN
Ocean Escorts:	
Escort Ship	DE
Guided Missile Escort Ship	DEG
Radar Picket Escort Ship	DER
Submarines:	
Submarine	SS
Submarine (nuclear propulsion)	SSN
Fleet Ballistic Missile Submarine (nuclear propulsion)	SSBN
Guided Missile Submarine	SSG
Patrol Ships:	
Patrol Escort	PCE
Patrol Rescue Escort	PCER
Patrol Gunboat	PG

(2) Amphibious warfare ships.

Amphibious Command Ship	LCC
Inshore Fire Support Ship	LFR
Amphibious Fire Support Ship	LFS
Amphibious Assault Ship (general purpose)	LHA
Amphibious Cargo Ship	LKA
Amphibious Transport	LPA
Amphibious Transport Dock	LPD
Amphibious Assault Ship	LPH
Amphibious Transport (small)	LPR
Amphibious Transport Submarine	LPSS
Dock Landing Ship	LSD
Tank Landing Ship	LST

(3) Mine warfare ships.

Mine Countermeasures Ship	MCS
Minehunter, Coastal	MHC
Minelayer, Coastal	MMC
Minelayer, Fast	MMD
Minelayer, Fleet	MMF
Minesweeper, Coastal (nonmagnetic)	MSC
Minesweeper, Coastal (old)	MSCO
Minesweeper, Fleet (steel hull)	MSF
Minesweeper, Ocean (nonmagnetic)	MSO
*Minesweeper, Special (device)	MSS

c. Combatant Craft.**(1) Patrol craft (note 1).**

Patrol Craft (hydrofoil)	PCH
Patrol Craft, Submarine	PCS
Patrol Gunboat (hydrofoil)	PGH
Fast Patrol Craft	PTF

(2) Landing craft (note 2).

Landing Craft, Assault	LCA
Landing Craft, Mechanized	LCM
Landing Craft, Personnel, Large	LCPL
Landing Craft, Personnel, Ramped	LCPR
Landing Craft, Utility	LCU
Landing Craft, Vehicle, Personnel	LCVP
Amphibious Warping Tug	LWT

(3) Mine countermeasures craft (note 2).

Minehunter, Auxiliary	MHA
Minesweeper, Auxiliary	MSA
Minesweeping Boat	MSB
Minesweeping, Drone	MSD
Minesweeper, Inshore	MSI
Minesweeping Launch	MSL
Minesweeper, River (Converted LCM-6)	MSM
Minesweeping, Patrol	MSR

(4) Riverine warfare craft (note 2).

Assault Support Patrol Boat	ASPB
Armored Troop Carrier	ATC
Command and Control Boat	CCB
Monitor	MON
Patrol Air Cushion Vehicle	PACV
River Patrol Boat	PBR
Patrol Craft, Inshore	PCF

d. Auxiliary Ships.

Destroyer Tender	AD
Degaussing Ship	ADG
Ammunition Ship	AE
Store Ship	AF
Combat Store Ship	AFS
Miscellaneous	AG
Escort Research Ship	AGDE
Hydrofoil Research Ship	AGEH
Environmental Research Ship	AGER
Miscellaneous Command Ship	AGF
Missile Range Instrumentation Ship	AGM
Major Communications Relay Ship	AGMR
Oceanographic Research Ship	AGOR
Radar Picket Ship	AGR
Surveying Ship	AGS
Auxiliary Submarine	AGSS
Technical Research Ship	AGTR
Hospital Ship	AH
Cargo Ship	AK
Cargo Ship, Dock	AKD
Light Cargo Ship	AKL

Note 1. Ship classifications in accordance with Article 2001, U.S. Navy Regulations.

2. Boat classifications in accordance with Article 2001, U.S. Navy Regulations.

*Not force level related.

Stores Issue Ship	AKS
Cargo Ship and Aircraft Ferry	AKV
Vehicle Cargo Ship	AKR
Net Laying Ship	ANL
Oiler	AO
Fast Combat Support Ship	AOE
Gasoline Tanker	AOG
Replenishment Oiler	AOR
Transport	AP
Self-propelled Barracks Ship	APB
Small Coastal Transport	APC
Repair Ship	AR
Battle Damage Repair Ship	ARB
Cable Repairing Ship	ARC
Internal Combustion Engine Repair Ship	ARG
Landing Craft Repair Ship	ARL
Salvage Ship	ARS
Salvage Lifting Ship	ARSD
Salvage Craft Tender	ARST
Aircraft Repair Ship (aircraft)	ARVA
Aircraft Repair Ship (engine)	ARVE
Aircraft Repair Ship (helicopter)	ARVH
Submarine Tender	AS
Submarine Rescue Ship	ASR
Auxiliary Ocean Tug	ATA
Fleet Ocean Tug	ATF
Salvage Tug	ATS
Seaplane Tender	AV
Advance Aviation Base Ship	AVB
Guided Missile Ship	AVM
Aviation Supply Ship	AVS
Auxiliary Aircraft Transport	AVT
Distilling Ship	AW
Fast Deployment Logistics Ship	FDL
Unclassified Miscellaneous	IX

e. Service Craft.

Large Auxiliary Floating Dry Dock (non-self-propelled)	AFDB
Small Auxiliary Floating Dry Dock (non-self-propelled)	AFDL
Medium Auxiliary Floating Dry Dock (non-self-propelled)	AFDM
Barracks Craft (non-self-propelled)	APL
Auxiliary Repair Dry Dock (non-self-propelled)	ARD
Medium Auxiliary Repair Dry Dock (non-self-propelled)	ARDM
Submersible Research Vehicle (nuclear propulsion)	NR
Target and Training Submarine (self-propelled)	SST
Submersible Craft (self-propelled)	X
Miscellaneous Auxiliary (self-propelled)	YAG
Open Lighter (non-self-propelled)	YC
Car Float (non-self-propelled)	YCF
Aircraft Transportation Lighter (non-self-propelled)	YCV
Floating Crane (non-self-propelled)	YD
Diving Tender (non-self-propelled)	YDT
Covered Lighter (self-propelled)	YF
Ferryboat or Launch (self-propelled)	YFB
Yard Floating Dry Dock (non-self-propelled)	YFD
Covered Lighter (non-self-propelled)	YFN
Large Covered Lighter (non-self-propelled)	YFNB

Dry Dock Companion Craft (non-self-propelled)	YFND
Lighter (special purpose) (non-self-propelled)	YFNX
Floating Power Barge (non-self-propelled)	YFP
Refrigerated Cover Lighter (self-propelled)	YFR
Refrigerated Covered Lighter (non-self-propelled)	YFRN
Covered Lighter (range-tender) (self-propelled)	YFRT
Harbor Utility Craft (self-propelled)	YFU
Garbage Lighter (self-propelled)	YG
Garbage Lighter (non-self-propelled)	YGN
Salvage Lift Craft, Heavy (non-self-propelled)	YHLC
Dredge (self-propelled)	YM
Salvage Lift Craft, Medium (non-self-propelled)	YMLC
Salvage Lift Craft, Light (self-propelled)	YLLC
Gate Craft (non-self-propelled)	YNG
Fuel Oil Barge (self-propelled)	YO
Gasoline Barge (self-propelled)	YOG
Gasoline Barge (non-self-propelled)	YOGN
Fuel Oil Barge (non-self-propelled)	YON
Oil Storage Barge (non-self-propelled)	YOS
Patrol Craft (self-propelled)	YP
Floating Pile Driver (non-self-propelled)	YPD
Floating Workshop (non-self-propelled)	YR
Repair and Berthing Barge (non-self-propelled)	YPB
Repair, Berthing and Messing Barge (non-self-propelled)	YRBM
Floating Dry Dock Workshop (hull) (non-self-propelled)	YRDH
Floating Dry Dock Workshop (machine) (non-self-propelled)	YRDM
Radiological Repair Barge (non-self-propelled)	YRR
Salvage Craft Tender (non-self-propelled)	YRST
Seaplane Wrecking Derrick (self-propelled)	YSD
Sludge Removal Barge (non-self-propelled)	YSR
Large Harbor Tug (self-propelled)	YTB
Small Harbor Tug (self-propelled)	YTL
Medium Harbor Tug (self-propelled)	YTM
Drone Aircraft Catapult Control Craft (self-propelled)	YV
Water Barge (self-propelled)	YW
Water Barge (non-self-propelled)	YWN

7-19. Marine Fleet Classification System

Each vessel in the transportation terminal battalion marine fleet bears an individual serial number, preceded by one of the following applicable prefixes:

BARC—lighter, amphibious (BARC), self-propelled, diesel, steel, 60-ton, 61-foot, design 2303.

BC—barge, dry cargo, nonpropelled, medium (100 feet through 149 feet).

BCDK—conversion kit, barge, deck enclosure.

BCI—barge, dry cargo, inland waterways, nonpropelled, medium (100 feet through 149 feet).

BCLI—barge, dry cargo, inland waterways, nonpropelled, large (150 feet and over).

BCP—barge, railroad carfloat.

BCS—nested barge.

BD—crane, floating.
 BDL—lighter, beach discharge.
 BG—barge, liquid cargo, nonpropelled.
 BGI—barge, liquid cargo, inland waterways nonpropelled.
 BK—barge, dry cargo, nonpropelled.
 BKI—barge, dry cargo, inland waterways, nonpropelled.
 BPL—barge, pier, nonpropelled.
 BR—barge, refrigerated, nonpropelled.
 BRI—barge, refrigerated, inland waterways, nonpropelled.
 BRO—barge, oil.
 BSP—barge, self-propelled.
 BSPI—barge, self-propelled, inland waterways.
 BT—barge, training, nonpropelled.
 F—fireboat.
 FB—ferryboat.
 FD—drydock, floating.
 FMS—repair shop, floating, marine repair, nonpropelled.
 FS—freight and supply vessel, large (140 feet and over).
 FSM—freight and supply vessel, medium (100 feet through 139 feet).
 FSR—freight and supply vessel, refrigerated cargo.

J—boat, work and inspection, small (50 feet and under).
 LARC—lighter, amphibious, resupply, cargo.
 LCM—landing craft, mechanized (Mark VI, Mark VIII).
 LCR—landing craft, retriever.
 LCU—landing craft, utility.
 LCVP—landing craft, vehicle, personnel.
 LT—tug, large (100 feet and over).
 LTI—towboat, large, inland waterways (100 feet and over).
 Q—boat, work and inspection, large (over 50 feet).
 R—rowboat.
 ST—tug, small (99 feet and under).
 STI—towboat, small inland waterways (99 feet and under).
 T—freight and supply vessel, small (under 100 feet).
 Y—vessel, liquid cargo, self-propelled.

7-20. Characteristics of Ships, Landing Craft and Amphibians

Tables 7-9 through 7-12 give some of the most essential characteristics of service ships, landing craft, and amphibians.

Table 7-9. Characteristics of Landing Ships

1	2	3	4	5	6	7	8	9	10	11	12
1 Name	Number ships in class	Type	Operational range (nautical miles)	Cargo capacity (LTONS)	Troop capacity ¹	Cargo space (sq ft)	Loaded draft		Length	Boat capacity	Typical loads
							Beaching	Oceangoing			
2 LSD (1)	26	Flooded well deck.	13,000	1,233	226	17,316	27'0" (flooded)	18'0" dry	458'0"	2 LCVP and 1 LCPL	3 LCU and 4-5 med trk; or 18 LCM (6) and 30 LTON cargo; or 41 LVT; or 27 LCVP; or 44 M48 tk.
3 LSD (28)	1	Flooded well deck.	13,000	2,410	353	19,800	30'0" (flooded)	19'0" dry	510'0"	3 LCVP and 1 LCPL	(With two temporary decks W ramps) 92 LVT.
4 LSD (32)	4	Flooded well deck.	9,500	2,500 in addition to rated well deck load.	313	24,792	33'9" (flooded)	19'0" dry	510'10"	3 LCVP and 1 LCPL	3 LCU; or 20 LCM (6); or 9 LCM (8); or 49 LVTP-5; or 87 LVTP-6.
5 LST (1156)	15	Ramp, 50-ton capacity.	6,000	Normal—446; Maximum landing—803; Full—1,395	395	14,000 vehicles 16,500 (cargo)	4'11" fwd 10'8" aft	8'3" fwd	382'0"	3 LCVP and 1 LCPL	80 2½-ton trk, 450 LTON cargo; or 144 ¾-ton trk, 415 LTON cargo; or 233 ½-ton trk, 530 LTON cargo; or 25 LARC-5, 445 LTON cargo.
6 LST (1153)	2	Steamdriven; ramp, 50-ton capacity.	7,700	Normal—446; Maximum landing—803; Full—2,060	197	14,340	3'11" fwd 11'11" aft	9'6" fwd 16'3" aft	382'0"	4 LCVP or 4 LCPR	21 LVT and 35 2½-ton trk; or 25 LARC-5; or 226,000 gal gasoline and 70,000 gal diesel fuel.
7 LST (542)	148	Ramp, 50-ton capacity.	7,706	Normal—446; Maximum beaching—803; Full—1,212	141	4,556 (vehicles). 9,772 (cargo)	5'3" fwd 10'2" aft	7'2" fwd 13'0" aft	328'0"	4 LCVP or 4 LCPR	26 2½-ton trk, 650 LTON cargo or 45 ¾-ton trk, 675 LTON cargo; or 75 ¼-ton trk, 710 LTON cargo or 23 LARC-5.
8 LST (1171)	8	Ramp, 75-ton capacity (equipped with turntable).	6,048	Normal—500 Maximum landing—900; Full—1,850	634	18,313	4'0" fwd 13'0" aft	9'9" fwd 16'0" aft	442'0"	3 LCVP and LCPL	19 LVTP-5 and CH-19 hel; or 27 LVTP-6 and 5 CH-19 hel; or 69 2½-ton trk; or 42 2½-ton trk W 1½-ton tir; or 42 M48 tk.

9	LSM	136	Ramp, open well.	10,000	Landing— 147; Full—446	56 2,900	3'6" fwd 7'1" aft	4½" fwd 8'5" aft	204'0"	-----	3 M48 tanks; or 5 LVT.
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¹ Troop capacity may be increased by berthing troops on decks. Troops must provide own feeding facilities.

² Add 6,836 sq ft with mezzanine deck installed.

Note 1. A boat space is the space weight allowed one soldier with his individual combat equipment. It is 224 pounds or 13.5 cubic feet. When computing boat spaces required for cargo, use either the weight or the space occupied, whichever is greater. Hand carts, loaded or empty, require two boat spaces.

Note 2. Running time may be computed from the formula $T = \frac{3D}{S}$ when
 D = Distance run in hundreds of yards.
 S = Speed in knots (1½ MPH).
 T = Running time in minutes.

Table 7-10. Characteristics of Small Landing Craft

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Name	Symbol	Length	Beam	Capacity		Draft (loaded)		Speed, loaded (knots)	Range (miles)	Crew	Weight (LTONS) empty	Cargo space dimensions
					Troop	Cargo (LTONS)	Forward	Aft					
2	Landing craft, vehicle, personnel.	LCVP	36'0"	10'5"	36 or	3.5	2'2"	3'0"	10.5	135	4	8	17'3" x 7'5" x 5'
3	Landing craft, mechanized (Mark VI).	LCM (6)	56'0"	14'0"	120 or	32.0	3'0"	4'8"	8.0	128 at 8 knots	4	28	37'6" x 11'0" x 6'4"
4	Landing craft, mechanized (Mark VIII).	LCM (8)	73'8"	21'0"	200 or	53.5	3'0"	5'0"	10.0	284	6	60	42' x 14'6" x 3'8"
5	Landing craft, utility (1466 class).	LCU	115'1"	34'0"	300 or	135.0	3'1'	4'0"	7.0	700	12	180	52' x 26'9" x 4'6" plus 22' x 14'4" x 4'6"
6	Landing craft, utility (1610 class).	LCU	135'3"	29'0"	400 or	170.0	3'3"	6'6"	11.0	-----	12	174	27' x 27' x 4'6" plus 53' x 18' x 4'6" plus 14' x 20' x 4'6" plus 11' x 13' x 4'6"

Table 7-11. Characteristics of Amphibious Vehicles

	1	2	3	4	5	6	7			8			9	10	11
1	Name	Symbol	Length	Beam	Capacity		Speed			Range			Crew	Weight (LTONS) Empty	Example of material carried
					Troop	Cargo (LTONS)	Land		Water	Land		Water			
							MPH	kmPH	Knots	Miles	Km	Nautical miles			
2	Carrier, cargo, amphibious, full-tracked.	M76	15'7"	8'2"	10	15.0	28	45	3.4	160	258	24.6	2	4.3	10 passengers (including crew).
3	Landing vehicle, tracked, engineer, model 1.	LVTE-1	39'9¼"	12'8⅞"	-----		24.9	40	5.4	185	298	120	8 (incl. engineers)	36.9	None

Table 7-11. Characteristics of Amphibious Vehicles—Continued

1	Name	Symbol	Length	Beam	Capacity		Speed			Range			Crew	Weight (LTONS) Empty	Example of material carried
					Troop	Cargo (LTONS)	Land		Water	Land		Water			
							MPH	kmPH	Knots	Miles	Km	Nautical miles			
4	Landing vehicle, tracked, recovery, model 1.	LVTR-1	31'9"	11'8½"	-----	-----	30	48	6.0	220	354	50	3	33.5	600 cubic feet available w/ recovery equipment removed from cargo compartment.
5	Landing vehicle, tracked, (MARK V).	LVTP-5	29'8"	11'8½"	34	9L 6W	27.8	45	6.7	187	301	45	3	31.2	105-mm Howitzer W crew and 100 rd ammo.
6	Landing vehicle, tracked,	LVT(A)-5	27'2½"	10'10"	-----	-----	20	32	5.6	150	242	50	5	15.7	None
7	Landing vehicle, tracked, (MARK VI).	LVTH-6	29'8"	11'8½"	-----	-----	27.8	45	6.7	187	301	45	6	37.8	None
8	Landing vehicle, tracked, (MARK VI).	LVTP-6	21'7"	10'9"	20	5L 4W	35	56	5.5	190	306	45	3	17.9	Bulk cargo
9	Lighter, amphibious, wheeled, (LARC-5).	LARC-5	35'0"	10'0"	24	4.4 (emerg)	30	48	8.7	400	644	50	3	8.5	Unitized general cargo.
10	Lighter, amphibious, wheeled, (LARC-15).	LARC-15	45'0"	14'6"	52	13.2 (emerg)	30	48	8.7	315	507	90	3	18.8	Unitized general cargo.
11	Lighter, amphibious, wheeled, (LARC-60).	LARC-60	62'6¾"	26'7"	125	53.6 (normal) 200 89.3 (emerg)	14	23	6.1	300	483	150	4	87.0	Personnel and large, heavy, bulky, out-sized equipment.

Note. No consideration need be made for the draft of amphibious vehicles. However, consideration must be given to the characteristics of the landing area which may affect beaching, such as mud, coral, or rock formations.

Table 7-12. Characteristics of Transport-Type Vessels

1	2	3	4	5	6	7	8	9	10	11
Name	Nr ships in class	Class	Type	Length	Loaded draft	Troop capacity	Cargo capacity (LTON)	Cargo space	Boat capacity	Cruising range (nautical miles)
2 Amphibious force flag-	16	-----	C-2	459'	24'0"	-----	-----	-----	2 LCVP	30,000

	ship (AGC).									4 LCPL 2 LCPR	
3	Attack transport (APA 117).	57	Haskell	-----	455'	24'0"	1,565	446.0	13,000 sq ft 110,000 cu ft	2 LCM(6) 22 LCVP 1 LCPL 1 LCPR	9,800
4	Attack transport (APA 33).	6	Bayfield	-----	492'	27'0"	1,647	446.0	15,000 sq ft 160,000 cu ft	4 LCM(6) 18 LCVP 3 LCPL 2 LCPR	11,630
5	Attack cargo ship (AKA).	35	Montague	C-2A	459'	24'0"	212	1,335.0-1,600.0	31,858 sq ft 291,706 cu ft	6 LCM(6) 14 LCVP 1 LCPL 1 LCPR 2 LCM(3)	12,000
6	High-speed transport (APD).	21	-----	EX-DDE	306'	13'0"	156	45.0	3,730 cu ft	2 LCVP 2 LCPR or 2 LCPL	5,100
7	Transport submarine (A-SSP).	2	Sea Lion	-----	312'	-----	85	26.7	-----	20 rubber land- ing craft.	-----
8	Roll-on/roll-off vehicle ship (T-AK).	1	Comet	C-4	449'	22'0"	-----	4,000.0 (375 veh)	60,000 sq ft parking space and 176,500 cu ft cargo space.	-----	13,000
9	Amphibious assault ship (LPH).	13	-----	EX-CVE	88'	28'9¼"	1,500	-----	-----	-----	16,000

CHAPTER 8

AIRCRAFT, AIRFIELDS, AND HELIPORTS

Section I. INTRODUCTION

8-1. General Concepts

Military areas within a theater of operations are shown graphically in figure 8-1 for fixed wing aircraft and in figure 8-2 for rotary wing aircraft. They include—

a. Battle Area. Sector of the battlefield normally under military control of a brigade.

b. Forward Area. Sector of the theater of operations immediately behind the battle area and normally under military control of a brigade or division.

c. Support Area. Sector of the theater of operations behind the forward area, normally within the army corps service areas or areas under

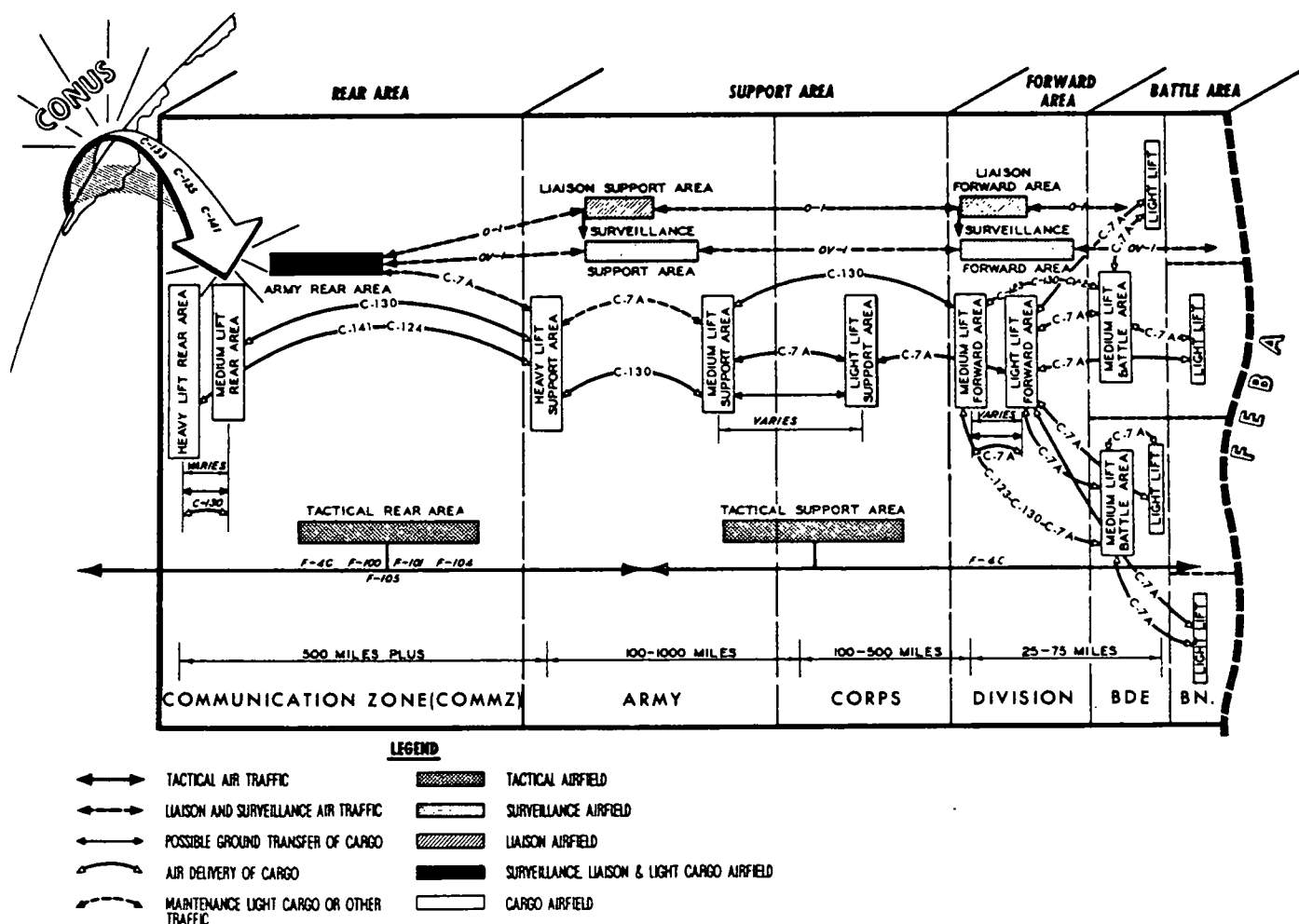


Figure 8-1. Theater of operations airfield concept, typical.

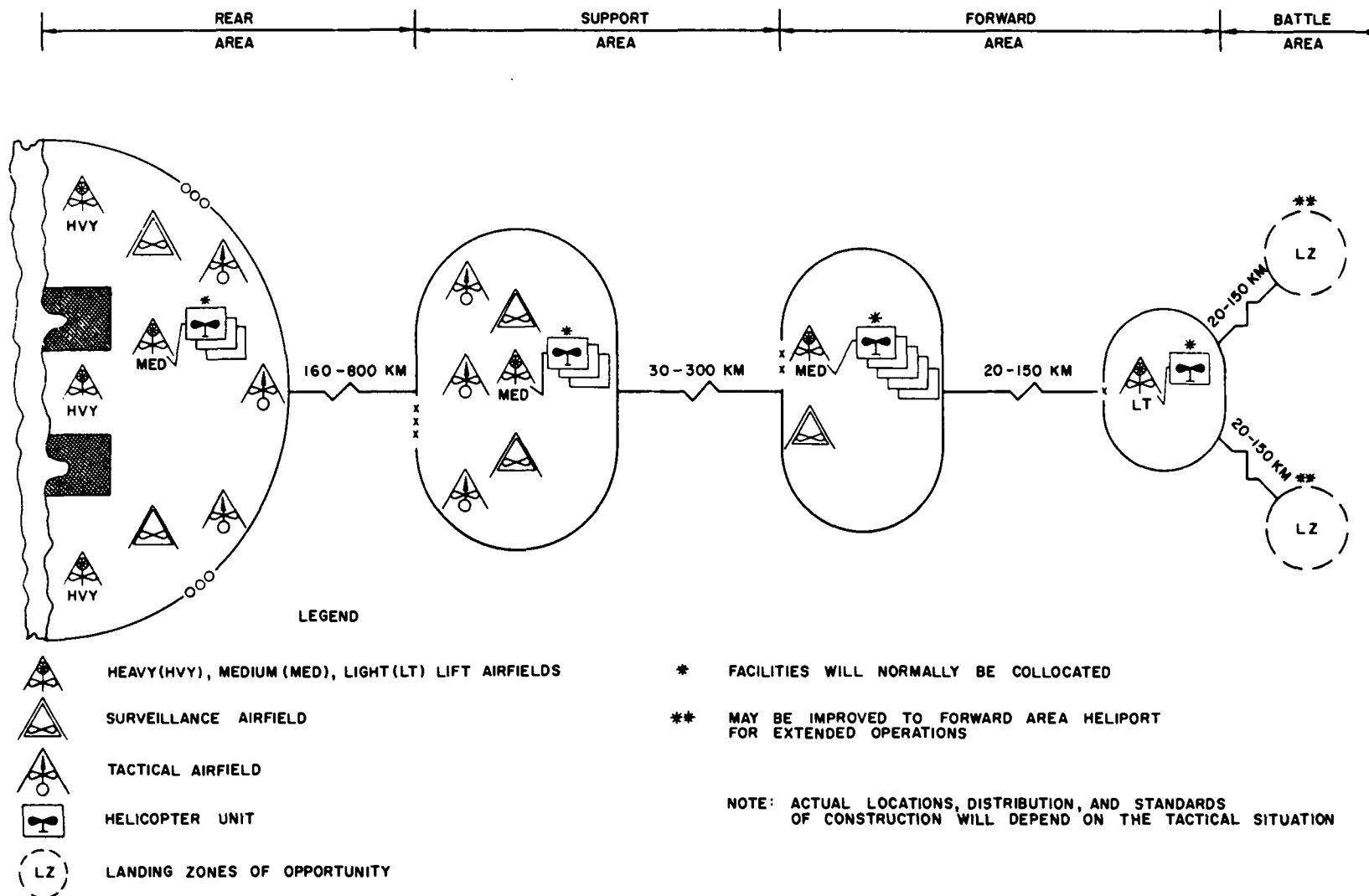


Figure 8-2. Theater of operations helicopter concept, typical.

military control of the field army support command.

d. Rear Area. Sector of the theater of operations behind the support area, normally within the army service area or the zone of communications.

8-2. Controlling Aircraft

a. Fixed Wing Aircraft. Aircraft are classified in six categories which embrace all fixed-wing aircraft in the current military inventory. A controlling aircraft, or combination of controlling aircraft, has been designated for each category to establish the airfield geometric and strength requirements. The categories and associated controlling aircraft are:

- (1) Liaison (O-1)
- (2) Surveillance (OV-1)
- (3) Light lift (C-7A)
- (4) Medium lift (C-130)
- (5) Tactical (F-4C and F-105)
- (6) Heavy lift (C-124, C-133, C-135, C-141, and C-5A).

As an example, designating the C-130 as the controlling aircraft for the medium-lift category insures that the facility will be adequate to accommodate other medium cargo aircraft such as the C-119 and C-123.

b. Rotary Wing Aircraft. Four helicopters

have been designated as controlling helicopters to establish the heliport geometric and strength requirements. These helicopters are—

- (1) Observation (light) helicopter (OH-6A)
- (2) Utility helicopter (UH-1D)
- (3) Cargo (medium transport) helicopter (CH-47)
- (4) Cargo (heavy lift) helicopter (CH-54)

8-3. Engineer Responsibilities

Engineer construction units, under the appropriate Army command, will be responsible for performing Air Force-Army construction on a general support and a direct support basis. The execution of large construction projects will normally be on a general support, that is, project directives, basis; units assigned in general support may be additionally assigned in direct support of a specific Army or Air Force element for emergency rehabilitation. Units, when executing either general or direct support missions, will remain under Army command and operational control. In executing emergency rehabilitation (direct support) plans, units will receive and accept detailed operational requirements from the supported commander (Army or Air Force). Normal maintenance of Air Force airfields is accomplished by the Air Force Civil Engineering Squadron.

Section II. FIXED WING AIRCRAFT AND AIRFIELDS

8-4. Aircraft Characteristics

The important characteristics of current Air Force aircraft are shown in table 8-1. Characteristics of Army aircraft are shown in table 8-2. Airfield criteria and layouts are based on usage by the critical aircraft. Less critical category types of aircraft may use the same facilities; more critical category aircraft may use these facilities only under special limitations.

8-5. Airfield Design Criteria

a. Geometric Requirements. Table 8-3 gives the minimum geometric requirements for airfields for the most likely using aircraft in the various military areas. Figures 8-3 and 8-4 give basic airfield layout. The circled numbers on figures 8-3 and 8-4 refer to columns in table 8-3, which in turn give the minimum dimension for

each element of the airfield. Figure 8-5 gives the nomenclature of the various elements involved.

b. Runway Length Determination. The runway is the ruling consideration in any airfield plan. Table 8-4 gives some of the key design characteristics of Army and Air Force aircraft, as they relate to the four different military areas. Figure 8-6 is a nomograph which permits rapid conversion of the aircraft takeoff ground run at sea level and 59° F (table 8-4) to required runway length at different altitudes, temperatures, runway grades and for different safety factors. Safety factors normally used in the theater of operations are 1.5 for rear area airfields, and 1.25 for support, forward, and battle area airfields. The dotted line on figure 8-6 illustrates the use of the nomograph to determine required runway length where a surveillance type airfield is to be

Table 8-1. Characteristics of Certain Air Force Aircraft

Aircraft		Dimensions			Performance			
Designation	Name	Wing span ft	Length ft	Height ft	Takeoff distance ground roll ft	Takeoff distance clr 50' OBST ft	Landing distance ground roll ft	Landing distance clr 50' OBST ft
A-7D	Corsair	38.7	46.1	16.1	5800	7800	3950	4950
A-26A	Invader	71.6	51.7	19.0	4075	4800	2390	3390
A-37B	-----	38.3	31.8	9.5	1590	2480	1380	2950
B-47E	Stratojet	116.0	107.1	28.0	10,400	12,000	4600	5500
B-52H	Stratofortress	185.0	156.0	40.8	6160	8120	2370	4480
B-57B	Canberra	64.0	65.5	15.5	5000	6200	2350	3100
RB-57F	Canberra	122.5	68.3	20.5	2600	2800	2800	4450
B-58A	Hustler	56.8	96.8	29.9	7850	13,700	2615	5285
RB-66B	Destroyer	72.5	75.2	23.6	6750	9350	3595	4915
FB-111A	-----	70.0	75.7	17.4	(*)	(*)	(*)	(*)
F-4E	Phantom	38.4	63.0	16.4	2940	3580	3300	4370
F-5A	Freedom fight.	25.3	47.2	13.2	6050	8100	3550	5400
F-86H	Saberjet	39.1	38.5	15.0	2310	3510	2950	3900
F-89J	Scorpion	60.0	53.8	17.5	3950	5700	2960	4130
F-100C	Supersabre	38.8	47.8	15.5	4175	6150	4080	5500
F-100F	Supersabre	38.8	52.5	16.2	5500	8200	4620	5180
RF-101H	Voodoo	39.7	67.9	18.0	3380	4630	4225	5170
F-102A	Delta Dagger	38.1	68.2	21.2	2290	3800	2500	5180
F-104G	Starfighter	21.9	54.8	13.5	5300	7930	2900	4590
F-105F	Thunderchief	34.9	67.0	20.5	4650	6500	4600	6370
F-106B	Delta Dart	38.3	70.8	20.3	2820	4540	4530	5970
F-111A	-----	32.0	75.5	17.1	4400	5500	1700	2400
C-5A	Galaxy	222.7	247.8	65.1	6020	6910	2175	3360
C-7A	Caribou	95.6	72.6	31.8	725	1200	825	1770
C-8A	Buffalo	96.0	77.3	28.7	1560	2200	900	1575
C-9A	-----	93.3	119.3	27.5	4380	5360	1756	2690
C-10A	-----	52.0	47.1	17.4	2330	3220	1325	2490
C-47D	Skytrain	95.0	64.4	16.9	2900	5100	2040	3210
C-54G	Skymaster	117.5	93.5	27.8	2780	5780	1918	3170
KC-97G	Strato tanker	141.2	110.3	38.3	6500	8150	3390	4690
KC-97L	Strato tanker	141.2	117.4	38.3	4600	5850	1590	2725
C-118A	Liftmaster	117.5	106.8	29.1	4350	5500	2500	3400
C-119G	Flying Boxcar	109.3	86.5	27.5	3180	5470	2236	3270
AC-119K	Flying Boxcar	109.3	86.5	26.3	2310	3700	2156	3097
C-121G	Super Const.	123.0	116.2	26.2	4030	5080	2660	3780
C-123K	Provider	110.0	76.2	34.5	1810	2802	1072	1797
C-124C	Globemaster	174.1	130.0	48.6	5520	7380	3200	4525
C-130E	Hercules	132.6	97.8	38.5	3600	5275	4150	5660
HC-130H	Hercules	132.6	100.2	38.5	3170	4650	1840	2875
C-131E	Samaritan	105.3	79.2	28.2	3580	5150	1770	2650
C-133B	Cargomaster	179.7	157.5	48.8	5040	5640	4385	6160
C-135A	Stratolifter	130.8	128.9	41.8	7200	8530	3470	5205
KC-135A	Strato tanker	130.8	136.2	41.7	10,200	12,840	1970	3390
C-140A	Jetstar	54.5	60.5	20.5	3670	5150	2050	2980
C-141A	Starlifter	160.7	145.0	39.3	2490	3360	1620	3480

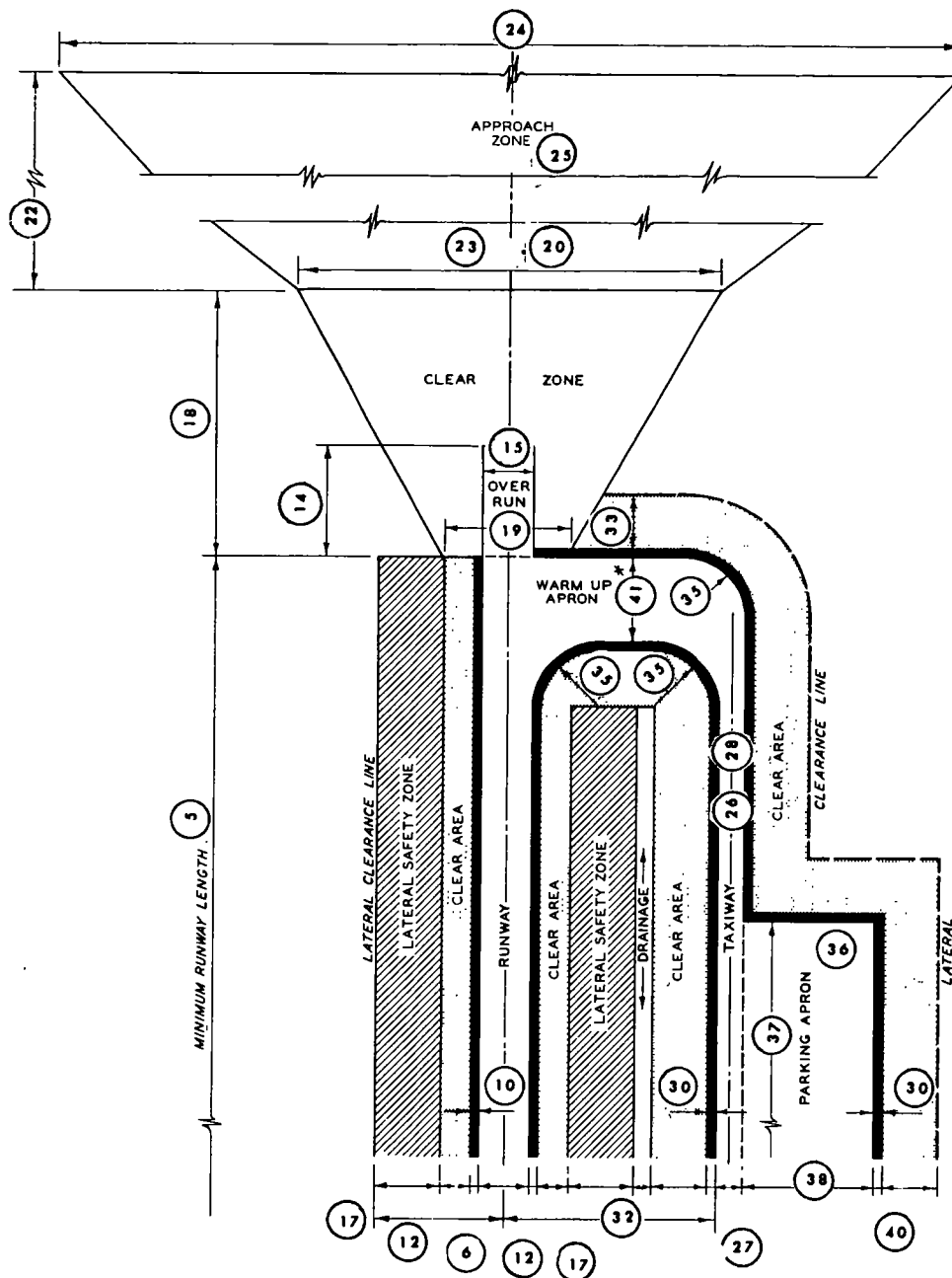
*Data classified.

Table 8-2. Characteristics of Certain Army Aircraft

Aircraft designation		Overall dimensions, ft			Weight, kips		Gear type	Main gear tires		Takeoff (hard surface) *	
Designation	Name	Length	Width	Height	Basic	Maximum takeoff		PSI	Contact area sq in.	Sea level ground run	0 Wind, ft clear 50 ft
O-1E	Bird Dog	25.8	36.0	7.5	1.61	2.4	Single-conventional	21	52	390	675
OV-1A	Mohawk	41.0	42.0	13.0	9.91	14.72	Single-tricycle (SN)	85	70	1005	1450
OV-1B	Mohawk	41.7	48.0	13.0	10.98	15.79	Single-tricycle (SN)	93	70	1410	2185
OV-1C	Mohawk	41.0	42.0	13.0	10.01	14.82	Single-tricycle (SN)	89	70	1440	2230
U-1A	Otter	42.0	58.0	12.4	4.90	8.0	Single-conventional	28	102	950	1630
U-6A	Beaver	30.5	48.0	10.4	3.10	5.1	Single-conventional	25	94	760	1080
U-8A	Seminole	31.5	45.3	11.6	4.99	7.3	Single-tricycle (SN)	35	73	1265	2155
U-8F	Seminole	33.3	45.9	14.2	5.49	7.7	Single-tricycle (SN)	35		1065	1660
U-10	Helio	30.3	39.0	8.8	2.01	3.8	Single-conventional	30		290	500
U-21A	Ute	35.8	45.9	14.2	5.38	9.5	Single-tricycle (SN)	46		1500	2000

Note. Basic Data Source, Army Aircraft Characteristics, Army Aviation Directorate, Office, Assistant Chief of Staff for Force Development, 1 March 1967.

* (C) FM 101-20.



* 94' IF COVERED BY MEMBRANE

I. PLAN VIEW (FIGURE REPRESENTS ONLY ONE—HALF OF LAYOUT, OTHER HALF IS IDENTICAL).

FOR MINIMUM GEOMETRIC REQUIREMENTS SEE TABLE 8-3. CIRCLED NUMBERS RELATE TO COLUMN NUMBERS AS LISTED IN TABLE 8-3.

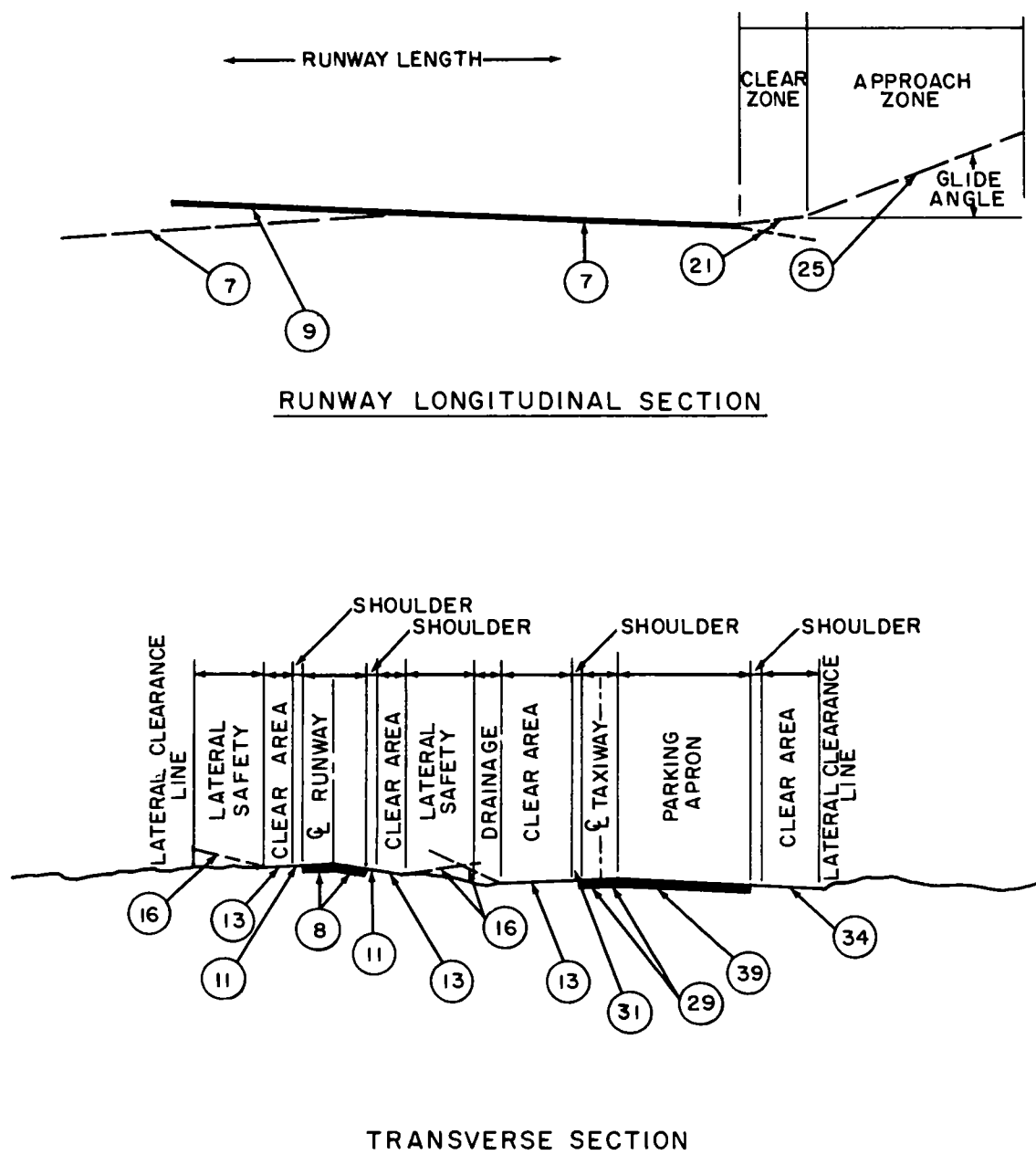
Figure 8-3. Basic airfield layout (excluding liaison airfields).

constructed at 1600 feet altitude, average maximum temperature being 79° and effective runway gradient 3 percent. Procedure is as follows:

(1) Enter nomograph on the left with the appropriate takeoff ground run from table 8-4.

(2) Proceed vertically from appropriate safety factor to safety factor line.

(3) Proceed horizontally into temperature correction chart to average maximum temperature as defined above.



2. LONGITUDINAL AND TRANSVERSE SECTIONS.

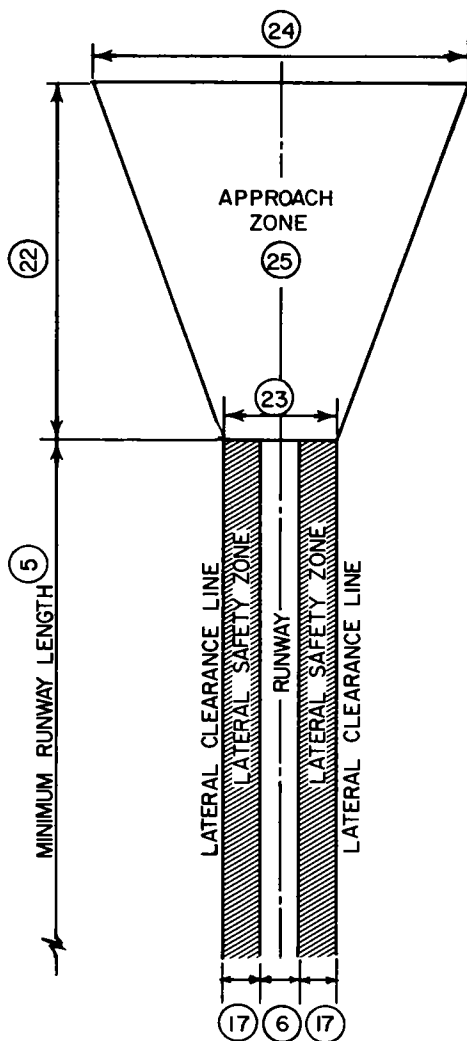
FOR MINIMUM GEOMETRIC REQUIREMENTS SEE TABLE 8-3. CIRCLED NUMBERS RELATE TO COLUMN NUMBERS AS LISTED IN TABLE 8-3.

Figure 8-3—Continued.

(4) Proceed parallel to slope of temperature correction chart to altitude correction chart. Proceed *horizontally* to operating altitude.

(5) Proceed parallel to slope of altitude correction chart to grade correction chart. Proceed *horizontally* to given design effective gradient.

(6) Proceed parallel to slope of grade correction chart to corrected runway length required. Raise value to next higher 100 feet and compare with minimum length as shown in column 5, table 8-3. (Use the larger figure.) This conversion may also be accomplished mathematically as outlined in TM 5-330.

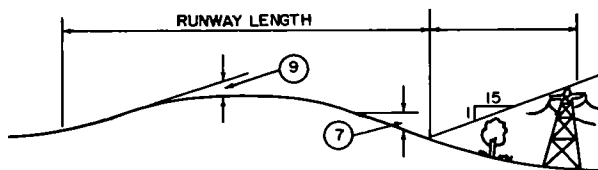


I. PLAN VIEW (FIGURE REPRESENTS ONLY ONE-HALF OF LAYOUT, OTHER HALF IS IDENTICAL).

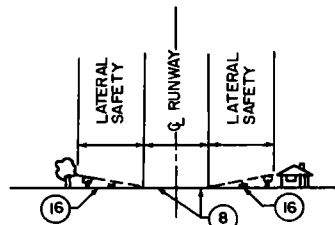
FOR MINIMUM GEOMETRIC REQUIREMENTS SEE TABLE 8-3. CIRCLED NUMBERS RELATE TO COLUMN NUMBERS AS LISTED IN TABLE 8-3

Figure 8-4. Layout of liaison type airfields.

c. *Thickness and Compaction Requirements.* Figure 8-7 illustrates the flexible pavement structure and compaction requirements for rear area full operational airfields. Where strength requirements are less, some layers may be omitted. Flexible pavement design must provide:



RUNWAY LONGITUDINAL SECTION



TRANSVERSE SECTION

2. LONGITUDINAL AND TRANSVERSE SECTIONS.

FOR MINIMUM GEOMETRIC REQUIREMENTS SEE TABLE 8-3. CIRCLED NUMBERS RELATE TO COLUMN NUMBERS AS LISTED IN TABLE 8-3.

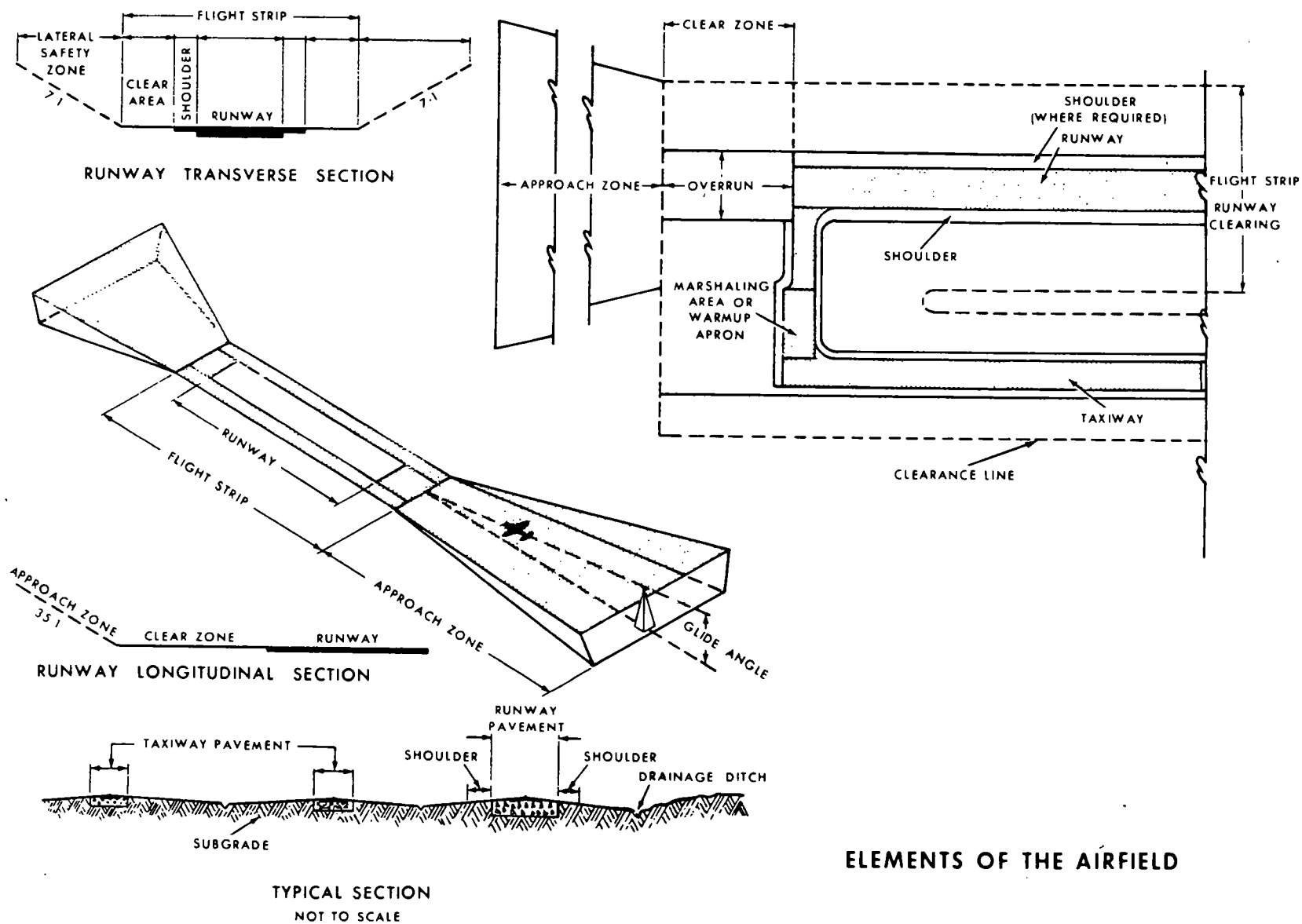
Figure 8-4—Continued.

Table 8-3. Minimum Airfield Geometric Requirements, Runway, Taxiway, and Apron (Located in back of manual)

(1) Sufficient compaction in the subgrade and each layer during construction to prevent objectionable settlement during traffic.

(2) Adequate thickness above the subgrade and above each layer, together with adequate quality of material in the select material, sub-base, and base courses to prevent detrimental shear deformation under traffic.

(3) A stable, weather-resistant, wear-resistant, waterproof, and in some cases a jet-fuel resistant pavement. Table 8-5 gives characteristics of soils pertinent to airfields. Table 8-6 gives basic airfield expedient surfacing requirements. For more technical and detailed design of airfield pavements, reference should be made to TM 5-330.



ELEMENTS OF THE AIRFIELD

Figure 8-5. Elements of the airfield.

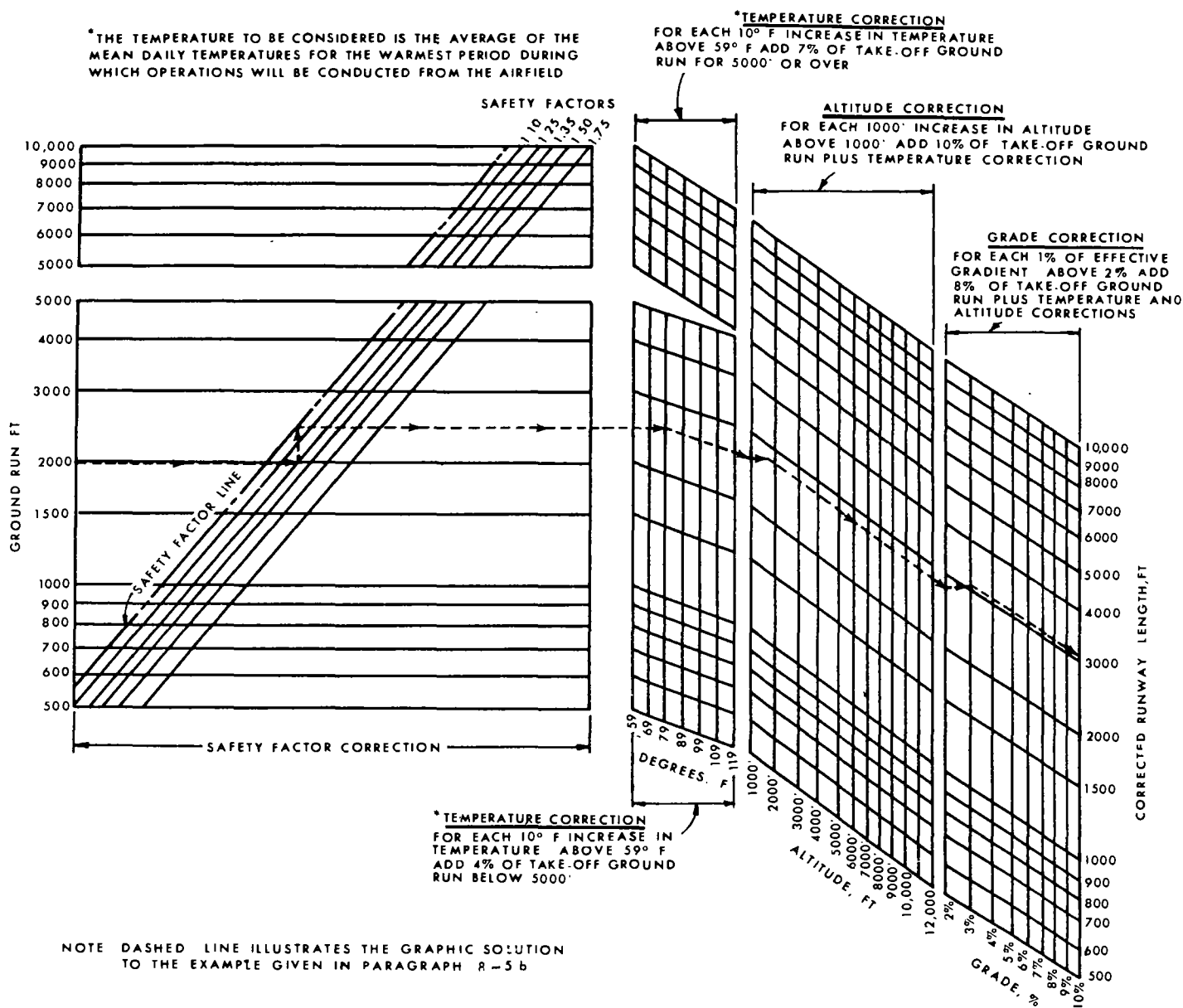


Figure 8-6. Runway length determination nomograph.

Table 8-4. Aircraft Characteristics Used in Design of Theater of Operations Airfield

Airfield type	Typical sector	Anticipated service life	Possible using aircraft U.S. type	Gross weight	Wing length segment used to compute dustproofing area, ft	Ground run at sea level and 69°, ft ^d
Battle area: Light lift Medium lift	Brigade base Brigade base	3 days	C-7A "	25,000	37	625
			C-130 "	100,000	60	1,600
			C-123	48,000	49	1,600
Forward area: Liaison	Division or brigade base.	2 weeks	O-1 "	2,400	15	390
Surveillance: Light lift	Division base		OV-1 "	15,800	20	2,000
	Division base		C-7A "	28,500	37	625

Table 8-4. Aircraft Characteristics Used in Design of Theater of Operations Airfield—Continued

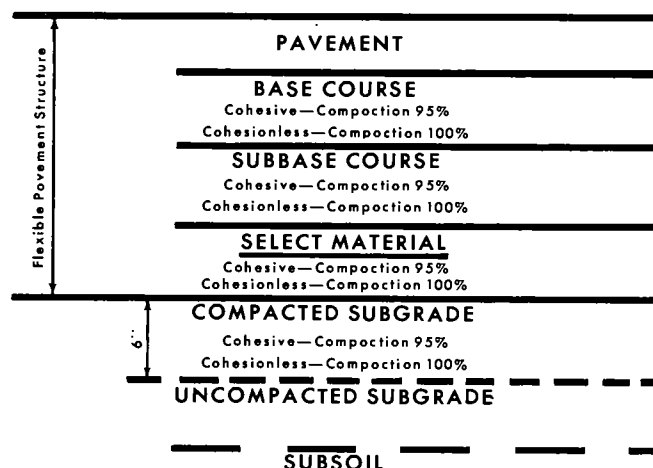
Airfield type	Typical sector	Anticipated service life	Possible using aircraft U.S. type	Gross weight	Wing length segment used to compute dustproofing area, ft	Ground run at sea level and 69°, ft ^d
Medium lift	Division base	1-2 months	C-130 ^a	110,000	60	2,000
			C-7A	28,500	37	625
Support area:						
Liaison	Corps area		O-1 ^a	2,400	15	390
Surveillance	Corps area		OV-1 ^a	15,800	20	2,000
Light lift	Corps area or FASCOM. ^b		C-7A ^a	28,500	37	625
Medium lift	Corps area or FASCOM.	6-12 months	C-130 ^a	130,000	60	2,800
			C-7A	28,500	37	625
Heavy lift	Corps area or FASCOM.		C-124 ^a	190,000	--	4,000
			C-141 ^a	260,000	73	2,400
Tactical	Corps area or FASCOM.		F-4C ^a	56,000	11	4,000
			F-101	51,000	--	4,000
Rear area:						
Army	COMMZ ^c		OV-1 ^a	15,800	--	2,000
			C-7A	28,500	37	625
			O-1	2,400	15	390
Medium lift	COMMZ		C-130 ^a	155,000	60	4,000
Heavy lift	COMMZ		C-141 ^a	316,000	73	3,900
			C-135 ^a	250,000	--	6,700
			C-133	300,000	82	5,300
Tactical	COMMZ		F-4C ^a	56,000	11	4,000
			F-105 ^a	53,000	--	5,300
			F-100	37,800	14	5,000
			F-101	51,000	--	4,000
			F-104	28,000	--	5,200

^a Particular aircraft that is critical in load and/or ground run from which area requirements, geometrics, and expedient surfacing requirements were developed.

^b Field Army Support Command.

^c Communications zone.

^d Runway lengths indicated are for classification and can undergo changes depending on operating weight of aircraft, pressure altitude corrections, temperature corrections and local conditions.



NOTE:

A cohesive soil is one with a PI above 5.

A cohesionless soil is one with a PI 0+5.

Percent compaction is as compared to modified AASHO (CE55) compactive effort

Figure 8-7. Recommended compaction requirements for rear area full operational airfields.



Table 8-5. Characteristics of Soils Pertinent to Battle, Forward, Support, and Rear Area Airfields

(Located in back of manual.)



Table 8-6. Basic Airfield Expedient Surfacing Requirements

(Located in back of manual.)

Section III. HELICOPTERS AND HELIPORTS

8-6. Helicopter Characteristics

Important characteristics of current Army helicopters are shown in table 8-7.

8-7. Geometrical Requirements for Heliports

It is considered that helicopter landings in the battle area will be in zones of opportunity and only minimum clearing or preparation will be made. For that reason, the following figures and tables are designed only for forward, support and rear area facilities. The geometrical layout is illustrated in figure 8-8 for heliports with taxi-hoverlanes and in figure 8-9 for heliports with

runways. Helipads constructed singly should have dimensions as indicated in table 8-8. Heliports may also be collocated with fixed wing airfields. TM 5-330 has detailed information on these installations. Table 8-8 is keyed by item numbers to figures 8-8 and 8-9 and gives minimum dimensions of heliports for the various type helicopters.

8-8. Standards of Construction

Table 8-9 gives the surfacing requirements of helipads and heliports for the commonly used aircraft in each designated area and for the existing airfield index.

Table 8-7. Helicopter Characteristics

Helicopter designation		Overall dimensions, ft			Weight, kips		Gear type	Design gear load, lb	Contact area sq in	Contact pressure, psi	Takeoff (hard surface)	
Design	Name	Length	Width	Height	Basic	Maximum takeoff					Sea level, ground run	0 wind, ft Clear 50 ft
OH-6A*	Cayuse	30.30	26.30	8.20	1.16	2.70	Skid	-----	180	14	0	0
OH-13S	Sioux	43.25	37.00	12.00	1.91	2.85	Skid	-----	---	---	0	---
OH-23G	Raven	43.25	35.16	10.16	1.91	2.80	Skid	1,250	---	---	0	210
OH-58A	Kiowa	41.00	35.30	9.60	1.59	3.00	Skid	-----	---	---	0	0
UH-1B	Iroquois	52.83	44.00	16.41	5.08	9.50	Skid	4,300	---	---	0	0
UH-1C	Iroquois	52.83	44.00	12.67	4.82	9.50	Skid	-----	---	---	0	0
UH-1D*	Iroquois	57.01	48.00	17.16	4.92	9.50	Skid	4,250	296	18	0	0
CH-34	Choctaw	65.83	56.00	15.83	7.76	13.30	Single-conventional	-----	---	---	0	0
CH-37B	Mojave	88.00	72.00	22.00	21.50	31.00	Twin-conventional	14,000	---	---	161	316
CH-47A*	Chinook	98.01	59.16	18.50	18.04	33.00	Twin-quad	12,225 Main	45 Main	138 Main	0	0
CH-47B	Chinook	99.00	60.00	18.67	19.59	40.00	Twin-quad	-----	---	---	0	0
CH-47C	Chinook	99.00	60.00	18.67	20.48	46.00	Twin-quad	-----	---	---	0	0
CH-54A*	Flying Crane	88.41	72.00	25.33	19.82	42.00	Single-tricycle	17,000 Main	94 Main	181 Main	0	0
AH-1G	Huey Cobra	52.97	44.00	11.00	----	----	Skid	-----	---	---	0	0

Note. Basic Data Source, Army Aircraft Characteristics, Army Aviation Directorate, Office. Assistant Chief of Staff for Force Development, 1 Jan 70.

*Particular helicopter that is critical in load and/or ground run from which area requirements, geometrics, and expedient surfacing requirements were developed.

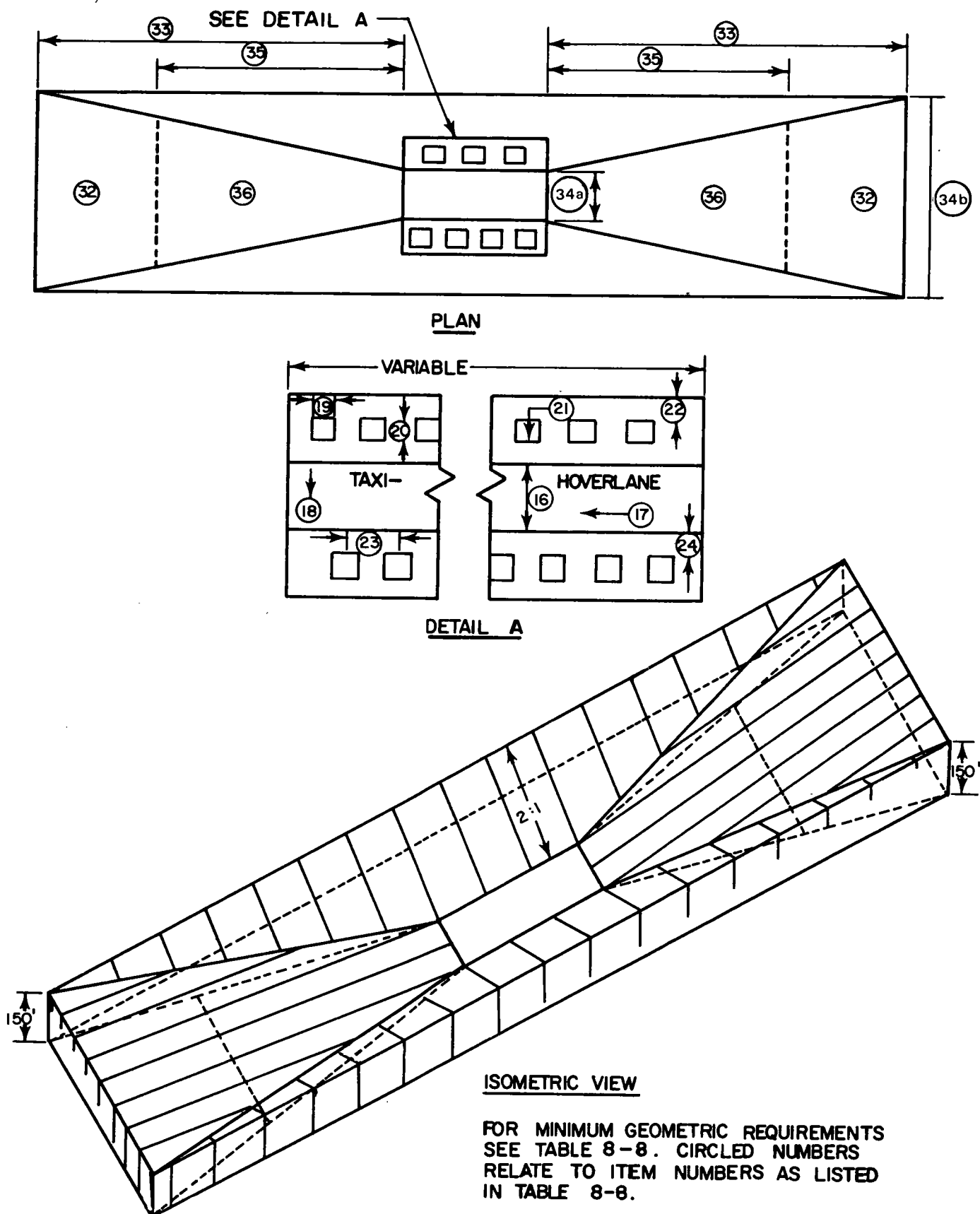


Figure 8-8. Geometric requirements for heliports with taxi-hoverlanes.

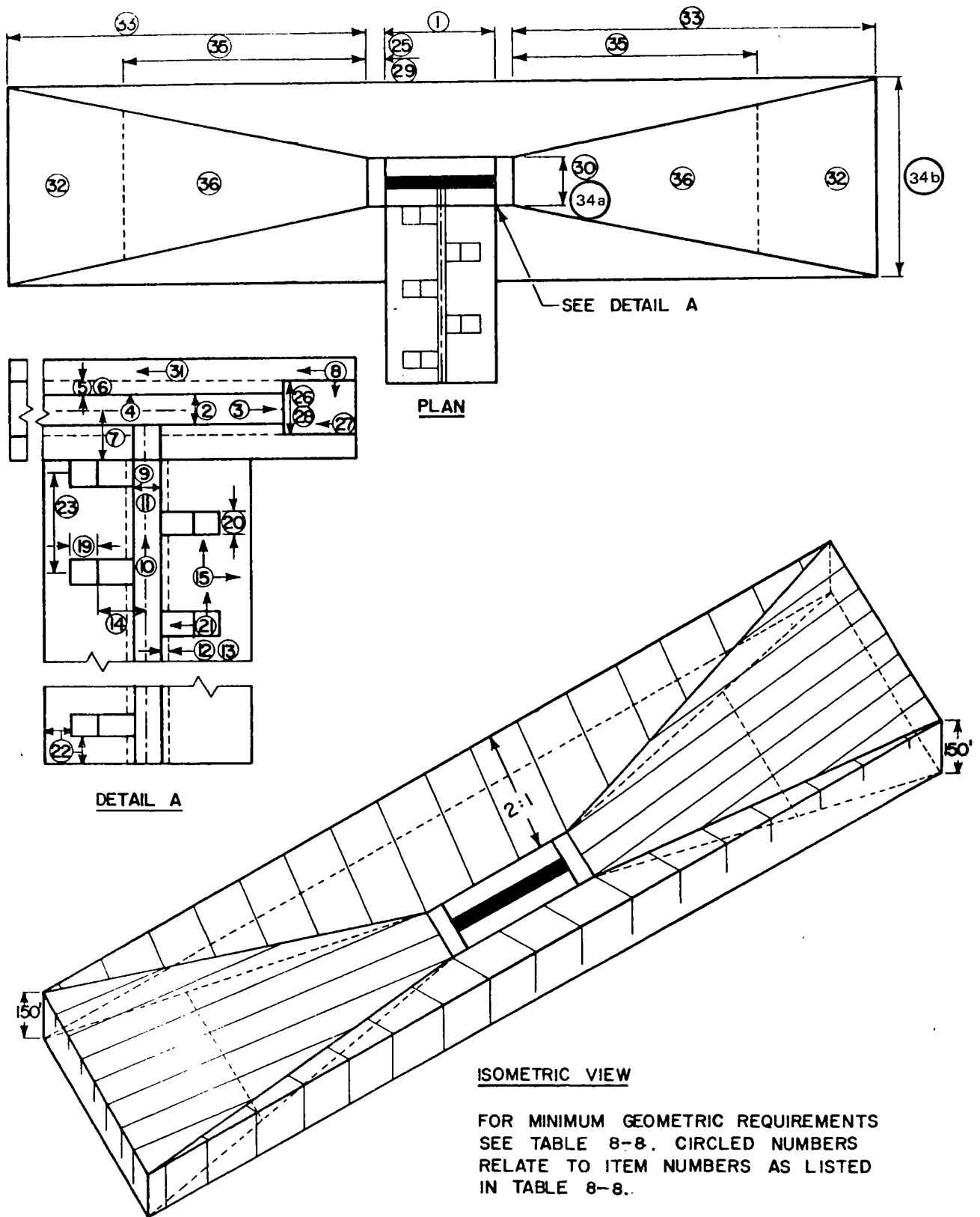


Figure 8-9. Geometric requirements for heliports with runways.

Table 8-8. Minimum Geometric Requirements for Heliports

Item No.	Description	Forward area				Support area				Rear area			
		OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54
					<i>Heliport runways</i>								
1	Length, ft ¹	----	----	----	----	----	----	450	450	----	----	450	450
2	Width, ft	----	----	----	----	----	----	25	50	----	----	40	60
3	Longitudinal grade of runways and shoulders, %	----	----	----	----	----	----	± 2	± 2	----	----	± 2	± 2
4	Transverse grade of runway, %												
	max	----	----	----	----	----	----	1.5	1.5	----	----	1.5	1.5
	min	----	----	----	----	----	----	.5	.5	----	----	.5	.5
5	Shoulder width, ft	----	----	----	----	----	----	10	10	----	----	25	25
6	Transverse grade of shoulders, %												
	max	----	----	----	----	----	----	3	3	----	----	3	3
	min	----	----	----	----	----	----	2	2	----	----	2	2
7	Clearance from runway C to fixed and/or movable obstacles, ft	----	----	----	----	----	----	125	125	----	----	125	125
8	Cleared areas, slope, % max	----	----	----	----	----	----	5	5	----	----	5	5
					<i>Heliport taxiways</i>								
9	Width, ft	----	----	----	----	----	----	25	40	----	----	40	60
10	Longitudinal grades of taxiways and shoulders, %	----	----	----	----	----	----	2	2	----	----	2	2
11	Transverse grade of taxiway, %												
	max	----	----	----	----	----	----	1.5	1.5	----	----	1.5	1.5
	min	----	----	----	----	----	----	.5	.5	----	----	.5	.5
12	Shoulder width, ft	----	----	----	----	----	----	10	10	----	----	25	25
13	Tranverse grades of taxiway shoulders, %												
	max	----	----	----	----	----	----	3	3	----	----	3	3
	min	----	----	----	----	----	----	2	2	----	----	2	2
14	Clearance from taxiway C to fixed and/or movable obstacles, ft	----	----	----	----	----	----	125	125	----	----	125	125
15	Grade in any direction in taxiway cleared area, %	----	----	----	----	----	----	5	5	----	----	5	5
					<i>Taxi-hoverlane</i>								
16	Width, ft ²	75	120	190	190	100	120	190	190	100	120	190	190
17	Longitudinal grade of Taxi-hoverlane, %												
	max	10	10	10	10	5	5	5	5	5	5	5	5

18	Transverse grade of Taxi-hoverlane, % max min	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5	5 1.5
<i>Heliport parking pad</i>													
19	Length, ft	12	20	50	50	12	20	50	50	25	40	50	100
20	Width, ft	12	20	25	50	12	20	25	50	25	40	100	100
21	Parking pad grade in any direction, % max min	3 .5	3 .5	3 .5	3 .5	1.5 .5	1.5 .5	1.5 .5	1.5 .5	1.5 .5	1.5 .5	1.5 .5	1.5 .5
22	Lateral clearance from rear and sides of parking pad to fixed and/or movable obstacles except other aircraft, ft	25	45	65	55	25	55	75	65	30	65	100	95
23	C-C spacing of parking pads ft	40	75	150	150	55	80	175	175	55	80	175	175
24	Spacing from edge of Taxi-hoverlane to edge of parking pad, ft ¹	10	20	20	20	10	20	20	20	10	20	20	20
<i>Heliport overrun</i>													
25	Length, ft	----	----	----	----	----	----	100	100	----	----	100	100
26	Width, ft	----	----	----	----	----	----	Same as runway plus shoulders					
27	Longitudinal grade, %	----	----	----	----	----	----	2	2	----	----	2	2
28	Transverse grade, % max min	----	----	----	----	----	----	3 2	3 2	----	----	3 2	3 2
<i>Heliport clear zone</i>													
29	Length, ft	----	----	----	----	----	----	100	100	----	----	100	100
30	Width, ft	----	----	----	----	----	----	250	270	----	----	250	270
31	Grades outside of overrun and shoulders, %	----	----	----	----	----	----	5	5	----	----	5	5
<i>Heliport approach-departure zone</i>													
32	Approach-departure surface ratio	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1	10:1
33	Length, ft	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
34	Widths, ft at end of clear zone or taxi-hoverlane at outer end	75 850	140 850	180 850	200 850	100 850	200 850	250 850	270 850	100 850	200 850	250 850	270 850
<i>Heliport takeoff safety zone</i>													
35	Length, ft	500	500	500	500	500	500	500	500	500	500	500	500
36	Width, ft	Same as approach-departure zone											

¹ Where runway length is not shown, takeoff and landing is on taxi-hoverlane.

² Taxi-hoverlane is used for takeoff and landing where provided.

³ Requirements are dependent upon parking scheme employed.

Table 8-8. Minimum Geometric Requirements for Heliports—Continued

Item No.	Description	Forward area				Support area				Rear area			
		OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54	OH-6A	UH-1D	CH-47	CH-54
37	Width, ft ⁴	11.5	11.5	11.5	<i>Service roads</i> 11.5	11.5	11.5	11.5	11.5	23	23	23	23

⁴ Roads should be located so as to require the least engineer effort.

Table 8-9. Basic Helipad and Heliport Surfacing Requirements

Helipad or heliport type	Anticipated service life	Runway, taxiway, apron, helipad, and road surfacing requirements for airfield index of									
		1-2	2-3	3-4	4-5	5-6	6-8	8-10	10-12	12-15	15 or greater
Forward area helipad											
OH-6A	2 weeks	LM	U	U	U	U	U	U	U	U	U
UH-1D	2 weeks	LM	LM	U	U	U	U	U	U	U	U
CH-47	2 weeks	I	MM	MM	LM	LM	LM	LM	U	U	U
CH-54	2 weeks	I	MM	MM	MM	LM	LM	LM	LM	U	U
Forward area heliport											
UH-1D Company	2 weeks	LM	LM	U	U	U	U	U	U	U	U
CH-47 Company	2 weeks	I	MM	MM	LM	LM	LM	LM	U	U	U
Support area helipad											
OH-6A	1-2 months	LM	U	U	U	U	U	U	U	U	U
UH-1D	1-2 months	LM	LM	U	U	U	U	U	U	U	U
CH-47	1-2 months	I	I	MM	MM	LM	LM	LM	U	U	U
CH-54	1-2 months	I	I	I	MM	MM	LM	LM	LM	LM	U
Support area heliport											
UH-1D Company	1-2 months	LM	LM	U	U	U	U	U	U	U	U
CH-47 Company	1-2 months	I	I	MM	MM	LM	LM	LM	U	U	U
CH-54 Company	1-2 months	I	I	MM	MM	MM	MM	LM	LM	LM	U
Mixed Battalion*	1-2 months	I	I	MM	MM	LM	LM	LM	U	U	U
Rear area helipad											
OH-6A	6-12 months	LM	LM	U	U	U	U	U	U	U	U
UH-1D	6-12 months	LM	LM	LM	U	U	U	U	U	U	U
CH-47	6-12 months	I	I	MM	MM	LM	LM	LM	LM	U	U
CH-54	6-12 months	I	I	I	MM	MM	MM	LM	LM	LM	U
Rear area heliport											
UH-1D Company	6-12 months	LM	LM	LM	U	U	U	U	U	U	U
CH-47 Company	6-12 months	I	I	MM	MM	LM	LM	LM	LM	U	U
CH-54 Company	6-12 months	I	I	I	MM	MM	MM	LM	LM	LM	U
Mixed Battalion*	6-12 months	I	I	MM	MM	LM	LM	LM	LM	U	U
Roads											
Forward	2 weeks	MM	LM	LM	LM	U	U	U	U	U	U
Support	1-2 months	MM	LM	LM	LM	LM	U	U	U	U	U
Rear	6-12 months	MM	MM	LM	LM	LM	U	U	U	U	U

Note. U—unsurfaced soil with or without membrane; MM—medium duty mat; LM—light duty mat; I—subgrade index must be increased to that required for medium duty mat.

* The surfacing requirements shown for the mixed battalion in the support and rear areas are for runways, taxiways, and aprons only. To determine the surfacing requirements for the landing pads, use those values shown for the individual helipads.

Section IV. EXPEDIENT SURFACING

8-9. Introduction

Landing mats and membranes are used as expedients for airfield surfacing. Landing mat is used when strength or smoothness of airfield surfaces is otherwise not adequate. Membrane surfacing is used where soil strength is adequate but where subsequent wetting may otherwise lead to reduction in soil strength to less than that needed. Membrane will be placed under all landing mat in high traffic area, i.e., runways and taxiways. In this case the membrane provides a waterproof covering for the soil. Membrane is also used to provide dust control in aircraft traffic areas where otherwise dust would be too great a problem and chemical dust palliatives are either less satisfactory or require greater time or effort to place.

8-10. Landing Mat

Two general categories of landing mat have been established, one for medium duty and one for light duty. The medium duty mat is a landing mat capable of sustaining 200 coverages of a 25,000 pound single-wheel load, with tire inflation pressure of 250 pounds per square inch and tire contact area of approximately 100 square inches, when placed on a subgrade with an airfield index of 6 (CBR of 4). The light duty mat is a landing mat capable of sustaining 200 coverages of a 25,000 pound single wheel load, with tire inflation pressure of 250 pounds per square inch on a subgrade with an airfield index of 11 (CBR of 10). Mats have been developed that meet all requirements for medium duty usage, including the weight requirement, but mats that will meet the weight requirements for light duty are not available. However, if the weight criterion is ignored, several mats can be utilized for light or medium duty on the basis of performance. Classification of the mats based on performance is—

Light-duty mat

M8A1^a

Medium-duty mat

MX19

MX18b

AM2

^a Formerly T10

In addition to these there is a past inventory mat, the M8 mat, which does not meet the referenced requirements for light- or medium-duty mat and will support only 20 percent of the volume of traffic (cycles) required of the light-duty mat. Table 8-10 gives mat characteristics. Tables 8-11 and 8-12 give minimum airfield and heliport area requirements. Number of bundles, weights and volumes of mat requirements can be calculated from data given. These calculations have been made and appear in tables in TM 5-330.

8-11. Membrane

The T17 membrane is a neoprene-coated, 2-ply, nylon fabric designed to provide a waterproof and dustproof wearing surface for soil subgrades used as landing areas and roadways. Membrane surfacing is furnished as Membrane Set, Runway Surfacing, Nylon FSN 5680-921-8730 and Membrane Set, Taxiway Surfacing, Nylon, FSN 5680-921-8731. The surfacing furnished for runway use is 66 feet wide and 100 feet long, and for taxiways the surfacing is 36 feet wide and 100 feet long. Since the membrane sets come in only two specific sizes, it will be necessary to (1) fit the individual sets to the areas desired surfaced, (2) use a combination of the sets, and in some cases, (3) cut, trim, and fit the surfacing for the intended use. To facilitate selection of membrane sets for surfacing airfields, enable rapid placement in the field, and provide economical use of the fabricated surfacing, the quantities of surfacing for airfields are shown in table 8-13. Care should be taken to prevent over-ordering membrane required and to eliminate waste of the surfacing when trimming the surfacing to size. Placement techniques, anchoring, repair, and maintenance are discussed in TM 5-337. Table 8-13 gives material requirements for T17 membrane for various type airfields.

Table 8-10. Mat Characteristics

	Mat type				
	M8A1	M8	M X 18b	MX19	AM2
Bundle dimensions (WxLxD), ft.	1.896 X 12.021 X 1.083	1.875 X 12.083 X 1.0	2.343 X 2.572 X 12.218	4.33 X 4.25 X 1.501	2.28 X 12.58 X 2.16
Volume of bundle, cu ft	24.7	22.7	74	85.7	62
Placing area in bundle, sq ft.	268.8	268.8	432	534.4	288
Area covered, sq ft, per cubic foot of cargo space.	10.88	11.84	5.8	6.24	4.64
Gross weight of bundle, lb	2036	1960	2400	2484	1980
Number of panels in bundle	13	13	16	32	11
Number of half-panels in bundle.	2	2	4	0	2
Panel placing dimensions (WXL), ft.	1.625 X 11.8125	1.625 X 11.8125	2.0 X 12.0	4.008 X 4.175	2.0 X 12.0
Panel depth (D), in	1.125	1.140	1.500	1.500	1.500
Panel weight, lb	144	140	120	68	140
Placing area per panel, sq ft.	19.2	19.2	24.0	16.7	24.0

Table 8-11. Minimum Airfield Area Requirements

Airfield type	Typical sector	Anticipated service life	Possible using aircraft US type	Mass parking apron area sq ft	Runway area sq ft	Overrun area sq ft	Taxiway area sq ft	Shoulder area sq ft	Warm-up apron area sq ft	Total aircraft traffic area ^a sq ft	Dust-proofing and/or water-proofing area ^b sq ft
Battle area:		3 days									
Light lift	Brigade base		C-7A °	None	50,000	7,500	42,000	48,000	28,000	120,000	308,000
Medium lift	Brigade base		C-130 ° C-123	None	120,000	12,000	73,000	88,500	30,000	223,000	778,000
Forward area:		2 weeks									
Liaison	Division or brigade base		O-1 °	None	37,500	None	None	None	None	37,500	62,500
Surveillance	Division base		OV-1 °	72,000	150,000	24,000	87,000	110,000	28,000	337,000	593,000
Light lift	Division base		C-7A °	72,000	72,000	24,000	48,000	58,500	28,000	220,000	482,000
Medium lift	Division base		C-130 ° C-7A	90,000	150,000	36,000	88,000	112,000	30,000	358,000	1,123,000
Support area:		1-2 mo									
Liaison	Corps area		O-1 °	None	50,000	None	None	None	None	50,000	82,500
Surveillance	Corps area		OV-1 °	180,000	180,000	36,000	102,000	130,000	28,000	490,000	806,000
Light lift	Corps area FAS-COM ^d		C-7A ° C-130 ° C-7A	778,000 374,000	90,000 210,000	36,000 36,000	57,000 142,000	73,500 152,000	28,000 27,500	953,000 753,500	1,306,000 1,759,000
Medium lift	Corps area or FAS-COM										
Heavy lift	Corps area or FAS-COM		C-124 ° C-141 °	403,000	600,000	50,000	389,000	218,000	29,000	1,421,000	3,271,000
Tactical	Corps area or FAS-COM		F-4C °	549,000	300,000	36,000	196,000	86,500	26,000	1,071,000	1,843,000
Rear area:		6-12 mo									
Army	COMMZ ^e		OV-1 ° C-7A O-1	518,000	216,000	43,000	122,000	133,000	25,500	882,000	1,456,000
Medium lift	COMMZ		C-130 °	1,670,000	432,000	72,000	232,000	268,000	27,500	2,362,000	4,007,000
Heavy lift	COMMZ		C-141 ° C-135 ° C-133	1,670,000	1,560,000	157,000	660,000	444,000	36,000	3,926,000	7,383,000

See notes below table.

Table 8-11. Minimum Airfield Area Requirements—Continued

Airfield type	Typical sector	Anticipated service life	Possible using aircraft US type	Mass parking apron area sq ft	Runway area sq ft	Overrun area sq ft	Taxiway area sq ft	Shoulder area sq ft	Warm-up apron area sq ft	Total aircraft traffic area ^a sq ft	Dust-proofing and/or waterproofing area ^b sq ft
Tactical	COMMZ		F-4 ^c F-105 F-100 F-101 F-104	549,000	864,000	216,000	540,000	504,000	36,000	1,989,000	2,922,000

^a Traffic area includes parking, runway, taxiway, and warm-up areas.

^b This area includes total traffic area plus overrun area plus an area around the inside and outside perimeters of the entire installation the width of the wing length segment shown in table 8-4.

^c Particular aircraft that is critical in load and/or ground run from which area requirements, geometrics, and expedient surfacing requirements were developed.

^d Field Army Support Command.

^e Communication Zone.

Table 8-12. Minimum Heliport Area Requirements ¹

Helipad or heliport type	Landing or parking pad sq ft	Taxiway sq ft	Runway sq ft	Overrun sq ft	Total traffic area sq ft ²	Total clear area sq ft ³	Dustproofing and/or waterproofing area sq ft ⁴
Forward area helipad	144	-----	-----	-----	144	5,184	20,100
OH-6A -----	400	-----	-----	-----	400	10,000	39,600
UH-1D -----	1,250	-----	-----	-----	1,250	18,750	177,000
CH-47 -----	2,500	-----	-----	-----	2,500	22,500	129,000
CH-54 -----							
Forward area heliport							
UH-1D Company -----	10,000	-----	-----	-----	10,000	313,100	373,300
CH-47 Company -----	20,000	-----	-----	-----	20,000	581,625	922,725
Support area helipad							
OH-6A -----	144	-----	-----	-----	144	11,025	20,100
UH-1D -----	400	-----	-----	-----	400	14,400	39,600
CH-47 -----	1,250	-----	-----	-----	1,250	22,500	177,000
CH-54 -----	2,500	-----	-----	-----	2,500	25,500	129,000
Support area heliport							
UH-1D Company -----	10,000	-----	-----	-----	10,000	455,100	494,700
CH-47 Company -----	20,000	82,000	11,250	5,000	118,250	969,625	1,394,688
CH-54 Company -----	20,000	91,125	22,500	10,000	133,625	625,375	838,500
Mixed Battalion -----	120,432 ⁵	92,688	11,250	5,000	229,370	2,022,175	1,994,000
Rear area helipad							
OH-6A -----	625	-----	-----	-----	625	11,025	20,100
UH-1D -----	1,600	-----	-----	-----	1,600	14,400	39,600
CH-47 -----	5,000	-----	-----	-----	5,000	22,500	177,000
CH-54 -----	10,000	-----	-----	-----	10,000	22,500	129,600
Rear area heliport							
UH-1D Company -----	40,000	-----	-----	-----	40,000	473,000	516,900
CH-47 Company -----	80,000	125,700	18,000	8,000	223,700	1,025,000	1,297,625
CH-54 Company -----	60,000	97,050	27,000	12,000	184,050	618,000	846,025
Mixed Battalion -----	241,875 ⁵	137,900	18,000	8,000	397,715	2,100,112	2,170,030

¹ For typical layouts see figures 8-8 and 8-9.

² Traffic area includes parking or landing pad, taxiway, and runway.

³ Total clear area is the area inside the lateral clearance line.

⁴ This area includes the total clear area and an area around the perimeter, the width of which is determined by rotor downwash.

⁵ Includes 80,000 square feet maintenance area.

Table 8-13. Material Requirements for T17 Membrane-Surfaced Airfields

Airfield type	Typical sector	Anticipated service life	Mass parking apron area (sq ft)	Runway area (sq ft)	Over-run area (sq ft)	Taxiway area (sq ft)	Shoulder area (sq ft)	Warm-up apron area (sq ft)	Total area (sq ft)	Total wt of T17 (lb)	Total vol of T17 (cu ft)	Wt of accessories * (lb)	Vol of accessories (cu ft)	Total wt of T17 and accessories (lb)	Total vol of T17 and accessories (cu ft)
Battle area:															
Light lift	Brigade base	3 days	None	56,350	8,453	47,334	54,096	31,556	135,240	44,629	2,421	24,478	1,068	69,107	3,489
Medium lift	Brigade base		None	135,240	13,524	82,271	99,740	33,810	251,321	82,936	4,499	45,489	1,985	128,425	6,484
Forward area:															
Liaison	Division or brigade base	2 weeks	None	42,263	None	None	None	None	42,263	13,947	757	7,650	334	21,597	1,091
Surveillance	Division base		81,144	169,050	27,048	98,049	123,970	31,556	379,799	125,334	6,798	68,744	3,000	194,078	9,798
Light lift			81,144	81,144	27,048	54,096	65,930	31,556	247,940	81,820	4,438	44,877	1,959	126,691	6,397
Medium lift			101,430	169,050	40,572	99,176	126,224	33,810	403,466	133,144	7,222	73,027	3,187	206,171	10,409
Support area:															
Liaison	Corps area	1-2 mo	None	56,350	None	None	None	None	56,350	18,596	1,009	10,199	445	28,795	1,454
Surveillance	Corps area		202,860	202,860	40,572	114,954	146,510	31,556	552,230	182,236	9,885	99,954	4,363	282,190	14,248
Light lift	Corps area or FASCOM		876,806	101,430	40,572	64,239	82,834	31,556	1,074,031	354,430	19,225	194,400	8,485	548,830	27,710
Medium lift			421,498	236,670	40,572	160,034	171,304	30,992	849,194	280,234	15,201	153,704	6,709	433,938	21,910
Heavy lift			454,181	676,200	56,350	438,403	245,686	32,683	1,601,467	528,484	28,666	289,866	12,652	818,350	41,318
Tactical			618,723	338,100	40,572	220,892	96,922	29,302	1,207,017	398,316	21,606	218,470	9,535	616,786	31,141
Rear area:															
Army	COMMZ	6-12 mo	583,786	243,432	48,461	137,494	149,891	28,738	993,450	327,839	17,783	179,814	7,848	507,653	25,631
Medium lift			1,882,090	486,864	81,144	261,464	302,036	30,993	2,661,411	878,266	47,639	481,715	21,025	1,359,981	68,664
Heavy lift			1,882,090	1,758,120	176,939	743,820	500,388	40,572	4,424,602	1,460,119	79,200	800,853	34,954	2,260,972	114,154
Tactical			618,723	973,728	243,432	608,580	568,008	40,572	2,241,603	739,729	40,125	405,730	17,709	1,145,459	57,834

* Accessories per 6,600 sq ft of T17 membrane. One crate contains: 26 steel anchors, two 5-gal pails of adhesive, ten 5-gal pails of nonskid compound, 2 rollers, 12 roller covers, and 2 roller handles.

Section V. AIRCRAFT REVETMENTS

8-12. Concept

Protective structures for Army aircraft are intended to provide increased protection against enemy ground fire and associated effects of exploding fuel and/or ammunition nearby. The selection of the type of structure to be used will depend on the threat level, available materials, engineer troops, and time. Generally conditions do not warrant construction of overhead shelters, but frequently revetments/bulkheads can be used to increase protection for aircraft. The revetments should be constructed as high as aircraft operations permit to minimize exposure of vulnerable parts of the aircraft above the revetment.

8-13. Definitions and Criteria

The following definitions, along with tables 8-12, 8-13, and 8-14 will be useful in planning and calculating quantities of materials required for construction of most common type revetments. TM 5-330 gives more detail and should be referred to before extensive revetment construction is undertaken.

a. Standoff. A standoff is a steel or wood curtain erected approximately 6 feet in front of a protective structure to detonate shells and thereby reduce the subsequent penetrating effect.

b. Condition. A construction "condition" as used herein refers to a protective structure with (conditions II and III) or without (condition I) a standoff (*a* above).

c. Gravity Revetment. A type of earth embankment in which earth is piled against a retaining wall at its angle of repose.

d. Earth Revetment. A type of earth embankment in which interior and exterior slopes are placed at the angle of repose.

e. Bulkhead. A bulkhead type of protective structure consists of two retaining walls with earth between the walls.

f. Free Standing Wall. A wall so constructed as to require no external braces or guying devices.

Table 8-12. Minimum Thickness of Protective Material Required to Resist Penetration*

Condition I—No Standoff
Material in Inches

Types of ammunition	Soil		Sand		Clay		Soil cement bituminous concrete	Con- crete	Timber	Alumi- num	Steel
	Wet	Dry	Wet	Dry	Wet	Dry					
.30 cal. ball (AP)	36	24	36	24	44	30	18	9	60	2.6	1.3
.50 cal. ball (AP)	54	36	45	30	80	54	18	9	120	4.4	2.2
57-mm recoilless rifle	18	12	18	12	36	24	20	10	20	9.0	5.0
82-mm recoilless rifle	40	27	41	27	80	54	42	22	48	21.0	12.5
90-mm recoilless rifle	60	40	63	42	120	80	66	33	76	32.0	19.5
107-mm recoilless rifle	72	48	70	48	144	96	84	42	88	40.0	22.5
60-mm mortar ²	72	48	45	30	100	64	20	10	20	2.8	1.0
81-mm mortar ²	90	60	63	42	136	90	26	18	27	3.7	1.3
120-mm mortar ²	103	70	70	48	180	120	32	16	36	4.7	1.7

Conditions II and III— $\frac{1}{4}$ Inch Steel or $\frac{1}{2}$ Inch Timber Standoff¹

.30 cal. ball (AP)	18	12	18	12	22	15	9	6	30	1.3	0.6
.50 cal. ball (AP)	27	18	26	15	40	27	9	6	60	2.2	1.1
57-mm recoilless rifle	9	6	9	6	18	12	10	6	10	4.5	2.5
82-mm recoilless rifle	20	13	21	13	40	27	21	11	24	10.5	6.3
90-mm recoilless rifle	30	20	30	21	59	40	33	17	38	16.0	9.3
107-mm recoilless rifle	36	24	35	24	71	48	42	21	44	20.0	11.3
60-mm mortar	36	24	22	15	50	32	10	5	10	1.4	.5
81-mm mortar	45	30	31	21	66	45	13	7	14	1.9	.6
120-mm mortar	52	35	35	24	90	60	16	8	18	2.4	.8

*Direct hit.

¹ Timber standoffs are ineffective against .30 and .50 cal. ball (AP) ammo. Therefore, if a timber standoff is used, design the structure as a condition II structure. Then determine if the structure will resist penetration by .30 and .50 cal. ball (AP) ammunition as a condition I structure. If not, increase the thickness of the standoff to the values found in the table for condition I opposite .30 and .50 cal. ball (AP) ammunition.

² Twelve-inch thick bulkhead revetments will defeat all fragments of mortar shells up to 120 mm detonated at the distances indicated:

Bulkhead walls
M8A1 Landing Mat
Plywood and Corrugated-Steel

Distance (ft)
5
30

Table 8-13. Inside Dimensions of Protective Structures for Parked Army Aircraft

Designation		Dimensions (ft)					
		Full protection			Partial protection		
Numerical	Name	Width	Height	Length	Width	Height	Length
		W	H	L	W _p	H _p	L _p
Rotary Wing							
OH-6A	Cayuse	37	10	43	16	5	30
OH-13S	Sioux	47	14	55	19	3	39
OH-23G	Raven	46	13	51	20	7	39
OH-58A	Kiowa	46	11	51	14	7	40
UH-1C ¹	Iroquois	54	14	63	25	6	50
UH-1B&D ¹	Iroquois	58	19	68	25	6	50
CH-34C	Choctaw	66	17	76	22	12	55
CH-37B	Mojave	82	20	98	38	15	75
CH-47A, B&C	Chinook	70	21	109	25	9	55
CH-54A	Flying Crane	82	27	106	35	11	90
AH-1G	Huey Cobra	46	14	54	25	4.8	50
Fixed Wing							
O-1E	Bird Dog	46	10	36	NA	NA	NA
OV-1A	Mohawk	52	15	52	NA	² 10	NA
OV-1B	Mohawk	58	15	52	NA	² 10	NA
OV-1C	Mohawk	52	15	52	NA	² 10	NA
U-1A	Otter	58	14	52	NA	NA	NA
U-6A	Beaver	58	12	41	NA	NA	NA
U-8D&F	Seminole	56	14	42	NA	² 9	NA
U-10		40	11	40	NA	NA	NA
U-21A	Ute	56	16	46	NA	NA	NA

Key to symbols:

W—entire aircraft is within the fortification.

H—entire aircraft is below the top of the fortification.

L—entire aircraft is within the fortification.

W—rotor blades overlap the walls of the fortification.

H—rotor assembly is above the top of the fortification, but engine and fuel cells should be protected.

L—rotor blades extend beyond the fortification walls.

Note. W, L, W_p and L_p provide for 10-foot clearance around the fuselage and H is 2 feet above aircraft except as noted.¹ Dimensions are for 48-foot rotor blade.² Complete tail assembly is exposed.

Table 8-14. Estimating Materials for 10-Foot
Sections of Fortifications
(Located in back of manual)

CHAPTER 9

POL DISTRIBUTION SYSTEMS

Section I. SYSTEMS AND CAPACITIES

9-1. The Role of Military Petroleum Pipeline Systems

a. In the European Theater during World War II, approximately 50 percent of the total logistical tonnage was petroleum fuels; during the Korean War and in support of the war in South-east Asia, this figure rose to about 60 percent.

b. The concept of mobile warfare with its increased mechanization dictate that in future conflicts there will be a considerable increase in the consumption of petroleum products by our Armed Forces.

c. More detailed information concerning responsibilities, systems, and requirements, can be found in TM 5-343 and TM 10-1101.

9-2. Bulk Supply Concept

Concepts for petroleum distribution in future warfare are based on maximum use of bulk supply methods.

a. Bulk Storage. Petroleum products will continue to be shipped overseas to dispersed ports or beachheads in large tankers. From these, it will be pumped through marine-dock or submarine (underwater) pipelines to major marine-terminal storage facilities. The storage facilities must be such that they offer an unprofitable target and are as secure as possible against weapons effects. To meet this requirement, onshore and inland storage facilities may consist of envelope type tanks (fabricated from fuel-impervious material) emplaced in large excavations for protection against nuclear-generated blasts and heat waves. Submersible (underwater) tanks for marine terminals are being investigated. These are not necessarily the only solutions to bulk storage problems for the future.

b. Distribution. From the marine-terminal storage facilities, the fuel will be pumped forward through rapidly extended pipelines to intermediate or pipehead tank farms. In forward

areas 500-gallon collapsible drums, collapsible tanks up to 50,000-gallon capacity, flexible hose-lines, and large capacity cross-country mobile tank trucks will be used. At the bulk reduction stations, fuels will also be dispensed into tank trucks, trailers, and aluminum and collapsible containers, ranging from 500- to 50,000-gallon capacity, belonging to the using units.

9-3. Classification of Military Petroleum Distributing Systems

a. General. Although pipeline systems may be considered as major or minor installations, it is difficult to define such a classification. For this reason, it is preferable to identify military pipeline systems according to their use or type of construction.

b. Types. When classified according to use, pipeline systems fall into three general types: assault, tactical, and logistical.

(1) An *assault* system generally is a temporary system which can be quickly installed to provide petroleum products to the using elements in assault or rapidly moving combat situations. An example of this type would be a hoseline laid like a firehose used to advance water from a hydrant to a fire.

(2) A *tactical* system is one that can be rapidly constructed and is capable of providing sufficient fuel for a corps or army. An example of this type system is the Army's coupled pipeline that follows the troops as closely and rapidly as possible.

(3) A *logistical* system is a more permanent or semipermanent system designed to provide large quantities of fuel to a stabilized area.

c. Construction. When classified according to construction, pipeline systems are subdivided into three types: welded, coupled, and hoseline. All are used in a typical military bulk distribution system.

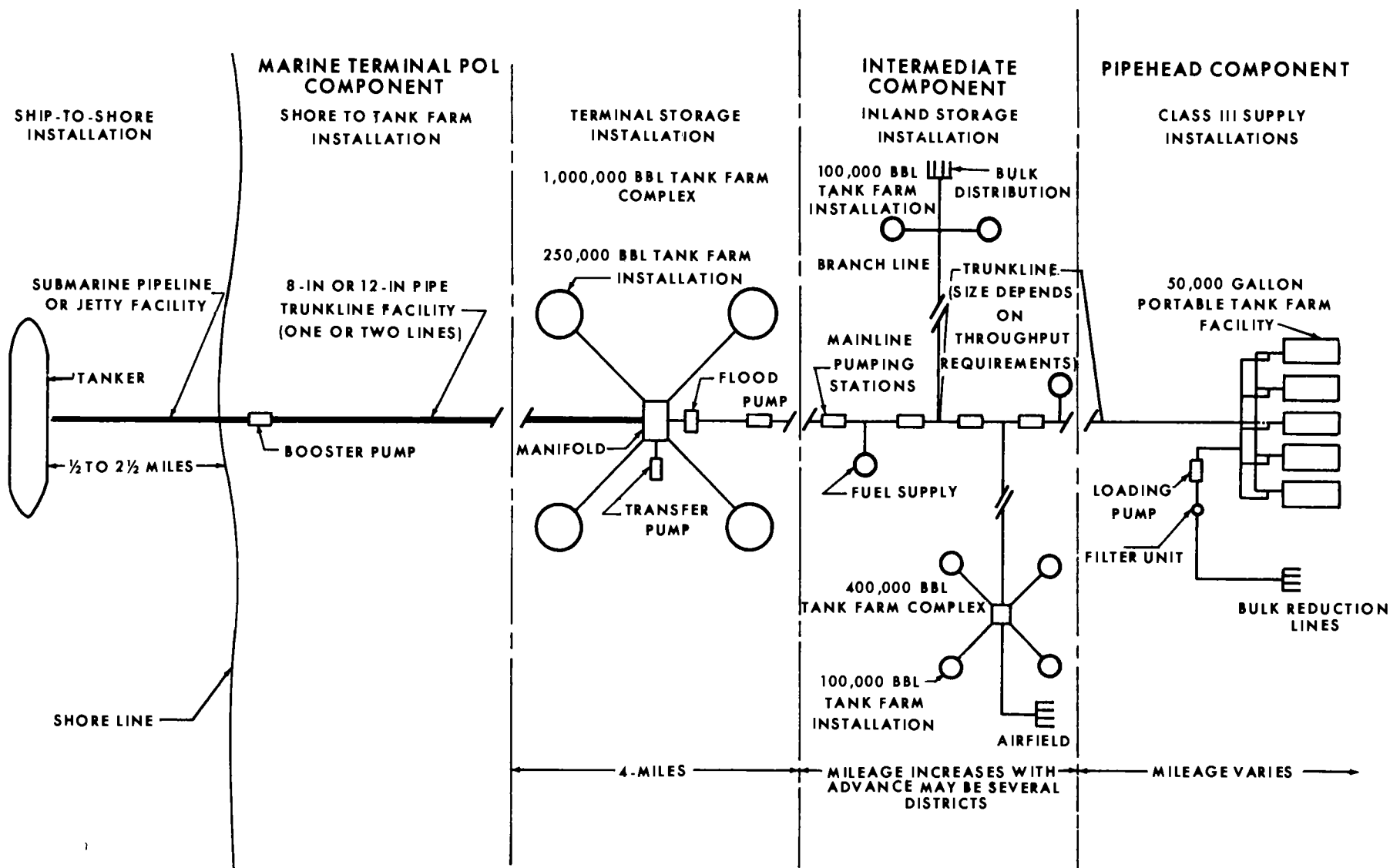


Figure 9-1. Schematic diagram of a petroleum bulk supply and distribution system in a theater of operations.

(1) At present, welded construction is used largely for ship-to-shore tanker unloading lines (submarine or dock) or at locations where buried pipelines (marine storage complexes, river and road crossings, etc.) are required.

(2) At present, coupled construction is employed for trunk and branch pipelines.

(3) Hoseline construction generally is used in support of assault operations, expedient situations, and the forward extension of the ever-moving military pipeline system.

9-4. Description of Military Bulk Supply and Distribution Systems

A military petroleum bulk supply and distribution system in a theater of operations usually is composed of a marine terminal, pumping stations, trunk pipelines, branch pipelines, intermediate and pipehead storage or tank farm complexes, bulk reduction points, and all appurtenances thereto. Figure 9-1 illustrates, in schematic form, a typical military petroleum bulk supply and distribution system. In consonance with the engineer functional components system, the system may consist of one or more of the following:

- a. Ship-to-shore tanker unloading (or loading) lines.
- b. Dockside loading or unloading facilities.
- c. Marine-terminal storage installation.
- d. Trunk or main pipelines.
- e. Branch pipelines.

f. Pump units.

g. Intermediate and pipehead storage installations.

h. Bulk reduction dispensing facilities.

i. Communications circuits.

Note. The construction of the above facilities and installations with the exception of communication circuits is the responsibility of the engineer command and may be erected either by engineer troops or under contract with commercial construction companies.

9-5. Capacities

The capacities of pipeline systems vary, depending on the size of pipe, gradient, location and size of pumps, and type of construction. Pipelines are capable of multiproduct operation. Welded commercial-type pipelines can be operated at much greater pressures than standard military coupled lines. For general planning purposes the pipeline capacities given in table 9-1 for standard military lightweight steel tubing may be used. Although military lightweight steel tubing ordinarily forms most of the length of a pipeline, it is normally not buried, nor is it used for submerged stream crossings or in populated areas and locations where hazards of fire and damage are acute. In situations where lightweight tubing is unsuitable, standard-weight, commercial-type (API) line pipe is the selected military standard for use in petroleum pipelines. TM 5-343 contains detailed information and data on pipeline equipment and a discussion of pertinent pipeline planning in considerations where deliberate planning estimates are needed.

Table 9-1. Capacity of Standard Military Lightweight Steel Tubing

	1	2	3	4	5	6	7
1	Nominal tubing size (in)	Normal design capacity (bbls per hr)	Emergency capacity (bbls per hr)	Safeworking pressure (psi)	Maximum working pressure (psi)	Gallons per day ¹	Net short tons per day
2	4	355	393	600	750	298,000	910
3	6	785	1,000	600	750	660,000	2,000
4	8	1,355	1,730	500	600	1,140,000	3,480
5	12	7,150	11,400	400	530	6,000,000	18,300

¹ Computed at normal design capacity, using an average operating day of 20 hours (average, all products).

Section II. PIPELINE SYSTEMS REQUIREMENTS

9-6. Basis of Requirements

Estimates of daily petroleum, oil, and lubricant (POL) requirements for a 12-division field army are based on a factor of 7 gallons per man per day. Requirements for this force vary from 3 million to 4 million gallons daily; for an eight-

division field army, they vary from 2 million to 3 million gallons per day, depending in each instance on the composition of the force and the tactical situation. However, for forces smaller than a 12-division field army, the 7-gallon-per-man-per-day factor tends to vary. When com-

munications zone (COMMZ) and tactical Air Force requirements are added to the field army requirements, the estimated total theater average may be increased to 6 million gallons per day to support a 12-division field army and to 4 million gallons per day to support an eight-division field army. In addition to the above estimated requirements, an estimate must be made of the amount of fuel that will be lost due to pilferage, sabotage, and damage to storage facilities and pipelines from direct enemy action. In hot climates allowance must also be made for evaporation and vapor losses. The POL system must provide the capacity to receive, store, maintain, distribute, and issue the types and quantities of fuels that these requirements represent. To satisfy this demand, six 8-inch pipelines, or two per corps, are required to support a 12-division force.

9-7. Bulk Petroleum Storage and Distribution

a. General. See TM 5-343 for descriptions, sizes, and operating characteristics of pipeline equipment; AR 701-5 for supply service responsibilities; and TM 10-1100 series for petroleum pipeline and terminal operating procedures and techniques. A complete pipeline system includes tanker discharge facilities and receiving tank farm at a port or beach (marine terminal); one or more parallel pipelines; tank farms, which are generally spaced from 80 to 120 kilometers apart along the system and vary from 50,000 to 1,000,000 barrel capacity, depending on supply needs and specified theater levels of supply; and dispensing facilities, which are provided at tank farms and supply points.

b. Pipelines. Four-, six-, and eight-inch diameter, lightweight pipe is standard for military pipeline systems. On level terrain pump stations are spaced 12.9 kilometers apart for 4-inch lines and 27 kilometers apart for 6- and 8-inch lines. Submarine ship-to-shore lines are 8-inch heavy welded lines and 12- to 16- and 20-inch concrete coated lines running from the offshore tanker mooring to the receiving tank farm. They are provided by the Corps of Engineers as part of

the equipment in marine terminal installation (*c* below). Table 9-2 provides POL pipeline construction requirements, including construction man-hours & rate of construction. For estimating troop requirements, an average engineer construction battalion, properly equipped, is considered to represent 125,000 man-hours of construction effort per month.

c. Tank Farms.

(1) To determine the amount of tank farm construction required in a theater of operations, the planner first determines the required theater level of supply. This may vary from a 30- to 60-day level, depending on the distance of tanker haul and probability of tanker losses through enemy action. Using the planning factor stated in paragraph 9-6, the amount of construction required may be estimated by the following formula:

$$\begin{aligned} &\text{Number of divisions (plus air support)} \times \\ &6,000 \text{ barrels per day} \times \text{number of days of} \\ &\text{level of supply} - \text{available existing storage} \\ &\text{in theater} = \text{total storage construction re-} \\ &\text{quirement. The Functional Components Sys-} \\ &\text{tem can provide tank farm installations of} \\ &\text{fourteen different throughout capabilities} \\ &\text{(6-, 8-, and 12-inch lines), and 50,000-,} \\ &\text{100,000-, 150,000-, 200,000-, and 250,000-} \\ &\text{barrel capacities. Each installation is made} \\ &\text{up of the same basic facilities; the difference} \\ &\text{lies only in the number and size of facilities} \\ &\text{used to provide the design capacity for any} \\ &\text{given installation. TM 5-301 and TM 5-302} \\ &\text{provide the needed information.} \end{aligned}$$

(2) Table 9-3 provides data for estimating tank farm construction along a pipeline system. These data include tanks, pipe manifolds to the individual tanks, pumps, valves, etc., necessary for operation of the tank farms. Current doctrine for dispersion of facilities prescribes that not more than 250,000 barrels of bulk storage capacity will be constructed within 6.5 kilometers of another tank farm. Tanks should be spaced at a minimum clear distance of at least two tank diameters. This may be increased up to 500 feet, but beyond that operating efficiency will be re-

Table 9-2. POL Pipeline Construction Requirements

1	2	3	4	5
Type	STON	MTON	Man-hours	Rate of Construction (km per day)
4-in. by 12.9 km with 355-BPH pump station	185	221	4,790	12.9
6-in. by 27 km with 785-BPH pump station	571	893	10,600	12.6
8-in. by 27 km with 1,355-BPH pump station	589	1,574	11,470	8.4

Table 9-3. POL Tank Farm Construction Requirements

1	2	3	4	5	6
Installation	Capacity (M bbl)	Site area (sq mi)	STON	MTON	Man-hours
2 Marine terminal, with submarine pipeline -----	200	110,000	1,454	2,453	49,280
3 Marine terminal, with jetty -----	200	-----	1,783	2,713	56,180
4 Marine terminal, with existing dock -----	200	-----	1,101	2,034	43,580
5 Marine terminal, with submarine pipeline -----	400	186,000	3,452	6,740	113,590
6 Marine terminal, with jetty -----	400	-----	3,493	6,660	115,830
7 Marine terminal, with existing dock -----	400	-----	2,811	5,981	103,230
8 Marine terminal, with submarine pipeline -----	1,000	440,000	6,650	13,147	242,800
9 Marine terminal, with jetty -----	1,000	-----	6,692	13,067	245,040
10 Marine terminal, with existing dock -----	1,000	-----	6,010	12,389	232,440
11 Tank farm, with 6-in. pipeline and accessories -----	50	42,000	372	575	12,975
12 Tank farm, with 8-in. pipeline and accessories -----	50	-----	397	610	13,621
13 Tank farm, with 6-in. pipeline and accessories -----	100	74,000	635	992	20,963
14 Tank farm, with 8-in. pipeline and accessories -----	100	-----	670	1,047	21,933
15 Tank farm, with 8-in. pipeline and accessories * -----	150	75,000	917	1,450	29,660
16 Tank farm, with 8-in. pipeline and accessories * -----	200	76,000	7,031	872	33,695
17 Tank farm, with 12-in. pipeline and accessories * -----	200	-----	7,801	1,033	34,689
18 Tank farm, with 8-in. pipeline and accessories * -----	250	102,000	1,420	2,228	45,025
19 Tank farm, with 12-in. pipeline and accessories * -----	250	-----	1,585	2,514	46,295
20 Tank farm, with 6-in. pipeline and accessories -----	400	152,000	2,642	4,186	81,155

* Using 10,000-barrel bolted steel tanks.

duced. When possible, advantage should be taken of available terrain features. Earth dykes should be constructed around all tanks, dykes to provide a reservoir capacity at least equal to the tank volume plus 1 foot of freeboard.

d. Pipeline Communications. A petroleum distribution system requires continuous communications between tank farm dispatchers, pump station operators, and pipeline patrol units. Signal support units provide both radio-voice and teletypewriter equipment for this communications system. Teletypewriter is used primarily for hourly recording of the flow of products along the pipeline and transmission of dispatching instructions between tank farms.

e. Pipeline Operations. Pipeline systems for distributing bulk petroleum fuels in the theater are operated by petroleum groups under the operational control of the TASCOT supply and maintenance command. Petroleum installations extend as far forward into the combat zone as possible. Liquid petroleum fuels can be moved most effectively and economically in bulk form. pipelines. Distribution of packaged petroleum fuels (5-gallon cans and 55-gallon drums) is restricted to the extent essential for adding flexibility to the system. Containers of POL smaller than 55-gallon drums are palletized when shipped to air terminals for subsequent airlanded delivery.



CHAPTER 10

BARRIER AND DENIAL OPERATIONS

Section I. PLANNING

10-1. General

FM 31-10 covers barriers and denial operations. Landmines are covered in FM 20-32, FM 20-32A, and TM 9-1345-200. FM 5-25 and TM 9-1375-200 deal with explosives and demolitions and FM 5-26 and chapter 10, FM 101-31-3 deal with atomic demolitions. FM 5-34 gives general field use information on all of the above subjects.

10-2. Barrier and Denial Operations

A barrier is a coordinated series of obstacles designed or employed to canalize, direct, restrict, delay, or stop the movement of an opposing force, and to impose additional losses in personnel, time, and equipment on the opposing force. A denial operation is designed to prevent or hinder enemy occupation of, or benefit from, areas or objects having tactical or strategic value. It may include

destruction, removal, contamination, or erection of obstacles.

10-3. Responsibilities

a. Barrier operations are undertaken at all levels of command and denial operations are normally planned at and coordinated by the higher levels of command such as independent corps, field army or theater. Thus, barrier operations may be considered as tactical support while denial operations have strategic implications. Both barrier and denial operations are coordinated in detail with the defense counter-attack, fire support, and combat service support plans of the units concerned.

b. Table 10-1 covers planning responsibilities for obstacles. The planning phases for engineer obstacles are covered in table 10-2.

Table 10-1. Obstacle Planning Responsibilities

Command	Pertinent points of commander's plans
Army -----	(1) Broad barrier plan for army area, including key bands. (2) Assignment of tasks to subordinate units. Covering forces construct covering barriers, and security forces on open flanks erect flank barriers. Army and corps troops install rear-area and flank barriers. (3) Limitations on use of obstacles in any particular area to insure coordination with general plans. (4) Emphasis on need for secrecy. Precautions must be taken to safeguard charts and maintain security of barrier plan. Broad plan should not go below division.
Corps -----	(1) Detailed barrier plan for corps area, made from map study, covering: (a) Location of natural and artificial barriers, including major minefields; (b) Location of lanes to be left open for counter-attack plans and supply. (2) Assignment of tasks to subordinate units including division and corps troops. (3) Close coordination of division plans. (4) Detailed siting of corps flank barriers. (5) Maps or overlays showing plan in enough detail so lower units will know exactly which barrier lines are to be installed or reinforced.
Division -----	Based on corps master plan: (1) Plan of bands or zones of obstacles and purpose each is to serve. (2) Timetable and priority of construction. (3) Demolition orders. (4) Routes to be kept open in accordance with tactical plan. (5) Need for secrecy. Detailed plan should not be in hands of front-line units. (6) Limitations on use of chemical agents. (7) Assignment of troops and equipment for construction and defense.

Table 10-2. Engineer Obstacle Planning

Plan phases	Phase details	Source of information
Map study -----	(1) Analyze all natural obstacles useful to mission of unit.	Maps, aerial photographs.
Reconnaissance -----	(2) Locate gaps and defiles in natural obstacles. (1) Locate individual obstacles from actual reconnaissance of terrain and determine effectiveness of each obstacle. (2) Determine type of artificial obstacle to use at each location or amount of work necessary to reinforce natural obstacle. (3) Estimate time, labor, and materials needed for each obstacle.	Engineer reconnaissance patrols, personal reconnaissance, combat patrols, and civilians.
General plans -----	(1) Indicate plan on map in graphic form showing location of each obstacle band and principal types of obstacles in band. (2) Prepare table of priority of construction, including time, labor, and material estimates. (3) Submit final plan for approval and coordination with tactical plan of unit commander.	Previous reconnaissance and map study, and orders from higher authorities.
Detailed plans -----	(1) Prepare detailed plans and orders ----- (2) Subdivide work, assign tasks to units, and issue orders.	Previous reconnaissance and map study.
Report -----	Submit report of completed obstacles to next higher commander.	

Section II. MINE WARFARE

10-4. Minefields

a. The various types of minefields are as follows:

(1) Protective minefields; used for close-in protection of small units in forward combat areas and units or installations in rear areas if infiltration, raiding, or sabotage is a threat. A protective minefield is simple, shallow in depth, and narrow in frontage.

(2) Defensive minefields; used as an element in the defense of organized and occupied tactical localities within a battle position.

(3) Barrier minefields; employed to block an enemy attack in certain areas and to canalize his advance into selected areas. Barrier minefields are laid in considerable depth.

(4) Nuisance minefields; employed to delay and disorganize the enemy and to hinder his use of an area or route.

(5) Phony minefields; used to make the enemy think that an area has been mined.

b. Logistical data on minefield operations are shown in table 10-3 and table 10-4. Tables 10-5 through 10-7 show logistical data on mines and related components. Figure 10-1 shows a standard minefield layout and markings. Tables 10-8 through 10-11 cover organization and equipment for minefield operations. Table 10-12 covers typical foreign mines.

Table 10-3. Minefield Data Summary Sheet.

(Located in back of manual)

10-5. Improvised Flame Mines

An improvised flame mine consists of a container, an incendiary fuel (usually thickened gasoline), and a firing system to scatter and ignite the fuel. The size of the area covered will depend upon the size of the firing device used. Variations of the basic flame field expedients are limited only by the imagination and initiative of combat personnel.

Table 10-4. Manpower, Material, and Transportation Requirements for Minefield Operations

Density			Strips rqr	Mines required			Crated mines		Vehicles required for crated mines		Man- hours	Meters of wire	Number of pickets
AT	Apers frag	Apers blast		AT	Apers frag	Apers blast	Weight in tons	Volume in cu ft	5T cargo (wt governs)	5T dump (vol governs)			
1	1	1	3	164	164	164	4.98	228.5	1.00	1.68	87	1200	30
1	2	2	3	164	312	312	5.85	260.1	1.17	1.91	120	1200	30
1	4	8	8	164	623	1213	7.82	337.8	1.57	2.47	234	2000	50
2	4	8	9	312	623	1213	11.44	512.7	2.29	3.76	279	2400	60
3	4	8	9	459	623	1213	15.05	686.7	3.01	5.03	323	2400	60

Explanatory notes.

1. AT, Apers Frag and Apers Blast mines are M15, M16, and M14 respectively.
2. Mine totals include IOE and 10% safety factor.
3. IOE cluster composition used is 1-2-2 (except for the 1-1-1 and 1-2-2 minefields where the IOE cluster composition is 1-1-1).
4. Man-hours are based on laying rate of 4 AT, or 8 AP fragmentation, or 16 AP blast mines per man-hour. Includes 20% factor to compensate for minefield siting, marking, and recording.
5. Quantities indicated are for 100 meter of front.
6. See table 10-3 for the recommended minimum density for minefield type.

Table 10-5. Service Antipersonnel Mines and Fuzes

Service Antipersonnel Mines					
Nomenclature	Packing description	Weight as shipped (lb.)	Shipping case dimensions (in.)		
			Length	Width	Height
MINE, ANTIPERSONNEL: M2 and fuze, mine, combination M6A1.	Packed 1 mine w/1 spool of four 26-ft length of steel wire/ctn, 10 ctn (10 mine w/accessories)/wdn bx.	93.4	32	13 1/4	9 1/2
MINE, ANTIPERSONNEL: M2A1, and fuze, mine, combination M6A1.	Packed 1 mine w/1 spool of four 26-ft length of steel wire/ctn, 10 ctn (10 mine w/accessories)/wdn bx.	93.4	32	13 1/4	9 1/2
MINE, ANTIPERSONNEL: M2A3 and fuze, mine, combination M6A1.	Packed 1 mine w1 spool of four 26-ft length of steel wire/ctn, 10 ctn (10 mine w/accessories)/wdn bx.	76.6	22 3/4	10 1/4	9 3/8
MINE, ANTIPERSONNEL: M2A4 and fuze, mine, combination M6A1.	Packed 1 mine w/1 spool of four 26-ft length of steel wire/ctn, 6 ctn (6 mine w/accessories)/wdn bx.	45.3	15	10 1/4	9 3/8
	Packed 1 mine w/1 spool of four 26-ft length of steel wire/ctn, 10 ctn (10 mine w/accessories)/wdn bx.	76.6	22 3/4	10 1/4	9 3/8
MINE, ANTIPERSONNEL: M3 and fuze, mine, combination M7A1.	Packed 4 mine w/4 fuze and 4 spool of steel wire/wdn bx.	---	-----	-----	-----
	Packed 6 mine w/6 fuze and 6 spool of steel wire/wdn bx.	75.6	17 7/8	8 3/4	9 1/2
MINE, ANTIPERSONNEL: M16 and fuze, mine, combination M605.	Packed 4 mine w/4 fuze M605/mtl cntr and 4 spool trip wire & 1 wrench M25/wdn bx.	44.8	15 5/8	10 1/8	8 1/2
MINE, ANTIPERSONNEL: M16A1 and fuze, mine, combination M605.	Packed 4 mine w/4 fuze M605/mtl cntr and 4 spool trip wire and 1 wrench M25/wdn bx.	44.8	15 5/8	10 1/8	8 1/2
MINE, ANTIPERSONNEL: M18 (T48) w/carrying kit M68 w/sights.	Packed 1/kit, 6 kit/wtrprf wrppd ctn, 1 ctn (6 mine)/wdn bx.	32.0	23 3/4	10 1/8	9 3/8
MINE, ANTIPERSONNEL: M18 (T48) w/carrying kit M68 (T66).	Packed 1 mine w/1 blasting cap and 1 battery holder assy in carrying kit M68, 6 kit (6 mine)/fbrbd ctn, 1 ctn/wdn bx.	41.0	23 3/4	10 1/8	9 3/8
MINE, ANTIPERSONNEL: M18 (T48) w/carrying kit M69 (T67).	Packed 5 mine w/5 electric blasting cap and 5 spool wire/carrying kit M69 (T67), 2 kit (10 mine)/wdn bx.	45	14 1/8	11 1/2	15 1/2
MINE, ANTIPERSONNEL: M18A1 w/accessories.	Packed 1 mine w/accessories in M7 band (6 mine and 6 band)/wdn bx.	---	-----	-----	-----
MINE, ANTIPERSONNEL: NM, M14 w/integral fuze.	Packed 90 mine/ctn (w/90 detonator M46 in set-up-box) and 6 wrench M22/wdn bx.	44.1	19 3/4	17 1/4	8 3/4
	Packed 90 mine/ctn (w/90 detonator M46 in set-up-box) and 9 wrench M22 wdn bx.	45.70	19 3/4	17 1/4	8 3/4
Service Antipersonnel Mine Fuzes					
FUZE, MINE: combination M6A1	Packed 3/ctn, 16 ctn (48 fuze)/wdn bx.	32.3	22 3/4	10 1/4	9 1/2
	Packed 3/crdbd ctn, 4 ctn/strprf pkg, 4 pkg (48 fuze)/wdn bx.	32.8	32 5/8	10 3/8	9 3/8
	Packed 3/ctn, 30 ctn (90 fuze)/wdn bx.	56.0	32	13 1/4	9 1/2
	Packed 3/ctn, 2 ctn/wtrprf pkg, 15 pkg (90 fuze)/wdn bx.	56.0	32	13 1/4	9 1/2
FUZE, MINE: combination M7A1	Packed 3/ctn, 16 ctn (48 fuzes)/wdn bx.	30.1	22 3/4	10 1/4	9 1/2
	Packed c/crdbd ctn, 4 ctn/wtrprf pkg, 4 pkg (48 fuze)/wdn bx.	33.0	22 5/8	10 3/8	9 3/8
	Packed 3/ctn, 2 ctn/wtrprf pkg, 8 pkg (48 fuzes)/wdn bx.	33.0	22 5/8	10 3/8	9 3/4

Table 10-5. Service Antipersonnel Mines and Fuses—Continued

Nomenclature	Packing description	Weight as shipped (lb.)	Shipping case dimensions (in.)		
			Length	Width	Height
	Packed 3/ctn, 30 ctn (90 fuze)/wdn bx.	56.0	32	13 1/4	9 1/2
	Packed 3/ctn, 2 ctn/strprf pkg, 15 pkg (90 fuze)/wdn bx.	56.0	32	13 1/4	9 1/2

Table 10-6. Service Antitank Mines, Fuzes, and Components

Service Antitank Mines					
Nomenclature	Packing description	Weight as shipped (lb.)	Shipping case dimensions (in.)		
			Length	Width	Height
MINE, ANTITANK: HE, heavy M15 w/fuze, mine, AT M603 and activator M1.	Packed 1 mine w/fuze and 1 activator, ea in can M182)/wdn bx.	49.0	18	15 1/8	7 1/2
MINE, ANTITANK: HE, heavy M21 and fuze, mine, combination M607 and booster M120.	Packed 2/wtrprf barrier bag, 2 bag (4 mine w/2 wrench M26)) wrbnd bx.	90.8	22 1/8	20 1/8	16
MINE, ANTITANK: He, NM, M19 (T18).	Packed 2 mines (w/2 fuze M606, 1 wrench M22 and 2 detonator holder assy in crdbd ctn, overpacked in barrier material bag and 2 activator M2 in indiv mtl cntr)/wdn bx.	71.8	16 3/8	10 3/8	16
MINE, ANTITANK: HE, NM, M19 (T18E4) w/fuze mine M606 (T1202E2).	Packed 2 mine (w/2 fuze and 1 wrench)/wdn bx.	71.8	16 3/8	10 3/8	16
MINE, ANTITANK: HE, NM, M19 w/fuze M606, w/activator M2).	Packed 2/support/bag, 2 bag (4 mine and 1 arming wrench M22)/wrbnd bx.	---	-----	-----	-----
MINE, ANTITANK: HE, heavy M6A2 w/fuze, mine, ATM603 and activator M1.	Packed 2 mine (w/fuze and 1 activator, each in indiv mtl cntr)/wdn box.	60.0	18 1/8	16	9 3/4
MINE ANTITANK: HE, heavy M6A2 w/fuze, mine, AT, M603 and activator M1.	Packed 1 mine (w/fuze and 1 activator, each in indiv mtl cntr)/mtl crate.	31.0	14	13 3/4	14 1/8
	Packed 1 mine (w/fuze each in indiv mtl cntr)/mtl crate.	29.0	14	13 3/4	14 1/8
Components of Service Antitank Mines					
ACTIVATOR, ANTITANK MINE: M1.	Packed 1mtl cntr, 100 cntr (100 activator)/wdn bx.	47.9	22 1/4	9 3/4	14 1/2
	Packed 1/mtl cntr, 132 cntr (132 activator)/wdn bx.	65.3	26 7/8	15 3/4	9 3/8
	Packed 1/mtl cntr, 144 cntr (144 activator)/wdn bx.	54.4	16 3/8	14 7/8	13 3/8
	Packed 1/mtl cntr, 168 cntr (168 activator)/wdn bx.	---	-----	-----	-----
ACTIVATOR ANTITANK MINE: M2 T3E1).	Packed 1/mtl cntr, 180 cntr (180 activator)/wdn bx.	54.5	16 3/8	16 3/4	14 3/4
ARMING PLUG, ANTITANK MINE: M4 or M4B1 (w or w/o spring).	Packed as required	---	-----	-----	-----
ARMING PLUG, ANTITANK MINE: M4 or M4B1.	Packed 144/wdn bx	70.0	15	13 3/8	11 1/2
BOOSTER, ANTITANK MINE: M120 (w/retainer).	Packed 200/ctn, 6 ctn (1,200 booster and 1,200 retainer)/wdn bx.	63.11	16 1/8	13 3/4	13 1/2
RETAINER, ANTITANK MINE BOOSTER.	Packed 25,000/fbrbd drum	93.0	16	16	18 1/2

Table 10-7. Logistical Mine Data Table

Note. Figures in parentheses indicate maximum load w/in 100 percent overhead capability &/or maximum volume of cargo space

Mine model & type	Weight (lb.) per mine	Mine packaging data					Capacity of indicated army vehicles				
		Number of mines, etc., per crate	Wt (lb.) per crate	Crate dimensions (in.)			M-35 2½-ton cargo truck (cargo space: 147 by 88 by 60 in.)				
				Length	Width	Height	Number of crates	How-carried	Number of types of crates	Total number mines	Total weight (tons)
M-21 AT -----	17.3	8, w/fuzes	90.8	22.13	20.13	16	55 (110)	Flat -----	2 (4)	220 (440)	2.49 (4.98)
M-15 AT -----	30.0	a. uncrated mines.	---	13.13 in diam.		5	---	Flat (flat, 11 on end)	3- (3)	166 (209)	2.49 (3.13)
		b. 1, w/fuze & activ.	49	19	15.13	7.5	103 (200)	Flat -----	3 (5)	103 (200)	2.53 (4.9)
M-19 AT -----	28.0	2, w/fuzes & activ.	80	16.25	10.5	16	63 (125)	On end (on side)	1 (3)	126 (250)	2.52 (5)
M18A1 -----	3.5	6(M-7 Kit)	53	14.25	11.5	17.25	100 (198)	On end (flat).	1 (5)	200 (396)	2.51 (4.97)
M2A4 AP -----	5.0	6, w/fuzes & wire.	50	15	10.25	9.5	100 (200)	Flat -----	2 (3)	600 (1,200)	2.5 (5)
M-3 AP -----	9.6	6, w/fuzes & wire.	72	18	8.75	9.5	70 (138)	Flat -----	2- (2+)	420 (828)	2.52 (4.96)
M-16 AP -----	8.0	4, w/fuzes & wire.	45	15.75	10.13	8.5	112 (222)	Flat -----	2 (4)	448 (888)	2.52 (4.99)
M-18 AP -----	2.5	a. 6(M-68 Kit).	33.1	20	11.5	9.75	151 (294)	Flat -----	4 (6)	905 (1,764)	2.49 (4.87)
		b. 10 (M-69 Kit).	45	14.25	15	17.25	112 (162)	Flat -----	2+ (3)	1,120 (1,620)	2.52 (3.64)
M-14 AP -----	0.2	90, w/dets. & wrenches.	44	19	18	8.75	114 (227)	Flat (on end).	4 3	10,260 (20,430)	2.5 (4.99)
Land chem (1 gallon) -----	11	uncrated 1.1 gal cans	---	4.13	6.56	10.56	---	On end standing	1 (2)	410 (820)	2.50 (5.00)
M-23 chem -----	22.75	uncrated mines	---	13 in diameter		5	---	Flat -----	2+ (5)	198 (396)	2.51 (5.02)
M-49 Static Flare.	1.4	a. 16, w/fuzes & wire.	44.9	21.25	14.5	11	111 (180)	Flat -----	3+ (5)	1,776 (2,880)	2.49 (4.04)
		b. 25, w/fuzes & wire.	59	21.25	14.5	11	84 (170)	Flat -----	3- (5)	2,100 (4,250)	2.47 (5)

Table 10-7. Logistical Mine Data Table—Continued

Mine model & type	M-105 1½-ton trailer (cargo space: 133 by 87 by 71 in.)					M-47 2½-ton dump truck (cargo space: 108 by 70 by 15 in.) (Volume is determining factor)				
	Number of crates	How carried	Number of tiers of crates	Total Number of mines	Total weight (tons)	Determine number of crates	Capacity how carried	Number of tiers of crates	Total number mines	Total weight (tons)
M-21 AT -----	33 (99)	Flat -----	2 (3)	132 (164)	1.50 (3.00)	23-----	On end ---	1	104	1.04
M-15 -----		Flat (on edge)	3 (2)	100 (200)	1.5 (3)	-----	On edge (or flat).	1 (3)	105	1.57
	51 (122)	Flat -----	2 4	61 (122)	1.49 (2.98)	56-----	On end ---	1	56	1.37
M-19 AT -----	37 (75)	Flat -----	1- 2	74 (150)	1.48 (3)	40-----	On end ---	1	80	1.6
M18A1 -----	59 (119)	Flat -----	2 (4-)	118 (238)	1.49 (2.99)	81-----	On end ---	1	162	2.03
M2A4 AP -----	60 (120)	Flat -----	1 (2)	360 (740)	1.5 (3)	70-----	On end (or flat).	1 (2)	420	1.75
M-3AP -----	41 (83)	Flat -----	1 (2-)	246 (498)	1.47 (2.98)	70-----	On end (or flat).	1- (2-)	420	2.52
M-16AP -----	66 (133)	Flat -----	1- (2+)	264 (532)	1.48 (2.99)	80-----	On end (or flat).	1 (2)	320	1.80
M-18 AP -----	90 (181)	Flat -----	3- (5)	540 (1,086)	1.48 (2.99)	63-----	On end ---	1	378	1.04
	66 (133)	Flat -----	2 (3)	660 (1,330)	1.48 (2.99)	28-----	Flat -----	1	280	.48
M-14 AP -----	68 (136)	Flat -----	3 (5)	6,120 (12,240)	1.49 (2.99)	48-----	On end ---	1	4,320	1.05
Land chem (1 gallon) -----	---	On end -----	1 (2)	273 (546)	1.50 (3.00)		On end ---	2	394	2.17
M-23 chem -----	---	Flat -----	1+ (3)	132 (264)	1.51 (3.02)		Flat -----	3+	170	1.93
M-49 Static Flare.	66 (132)	Flat -----	2 (4-)	1,056 (2,112)	1.48 (2.96)	42-----	On end ---	1	672	.94
	50 (101)	Flat -----	2 (3-)	1,250 (2,525)	1.47 (2.97)	42-----	On end ---	1	1,050	1.23

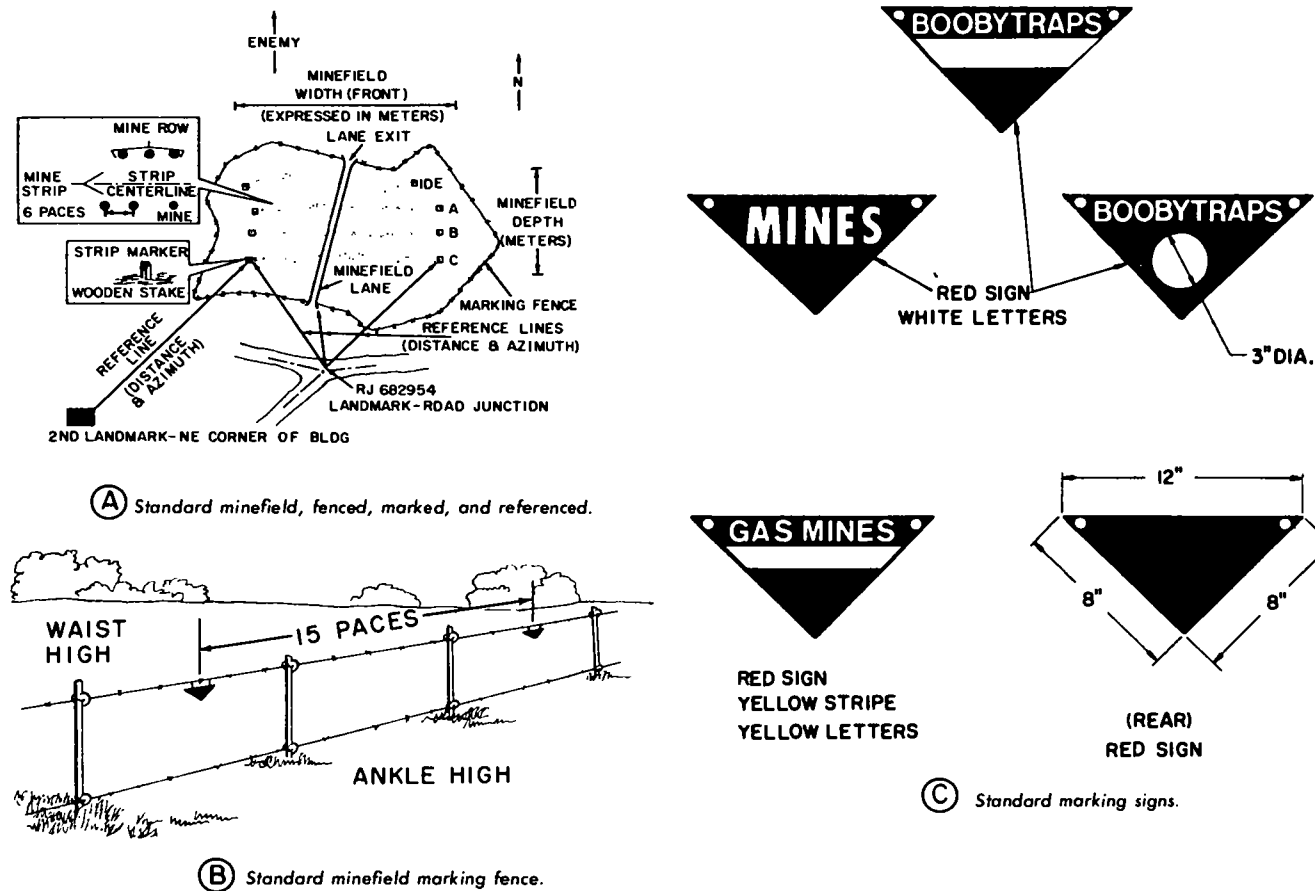


Figure 10-1. Standard minefield and markings.

Table 10-8. Platoon Organization and Equipment for Minefield Laying

Personnel	Officer	NCO	EM	Equipment
Supervisory Personnel	1	1	---	Officer: Map lensatic compass, notebook, and DA form 1355. NCO: Map, notebook, and lensatic compass.
Siting Party	---	1	3	Stakes or pickets, sledges, hammers, tracing tape on reels, and nails to peg tape.
Marking Party	---	1	2	Barbed wire on reels, pickets, marking signs, lane signs, wire cutters, gloves, and sledges.
Recording Party	---	1	2	Sketching equipment, lensatic compass, DA Form 1355, map and metric tape.
1st Laying Party	---	1	6 to 8	Notebook for squad leader, picks, shovels, and sandbags.
2d Laying Party	---	1	6 to 8	Same as 1st laying party.
3d Laying Party	---	1	6 to 8	Same as 1st laying party.
Totals	1	7	25 to 31	

Table 10-9. Platoon Organization and Equipment for Manual Breaching

Personnel	Officer	NCO	EM	Equipment
Officer in Charge	1	---	---	Lensatic compass, map, radio, and individual weapon.
Platoon Sergeant	---	1	---	Same as OIC, except without radio.
No. 1 Breaching Party	---	1	7	Two portable detectors, two probes, mine markers, marking tape or wire on reels, safety pins, clips, smooth wires (18" lengths) ½-lb blocks of explosive, blasting caps, detonating cords, safety fuze, fuze lighters, crimpers, and portable radio.
No. 2 Breaching Party	---	1	7	Same as No. 1 breaching party.
No. 3 Breaching Party	---	1	7	Same as No. 1 breaching party.
Support Party	---	1	10	Same as No. 1 party, plus: sledges or mauls, hammers, pliers wire cutter, 2" by 4" stakes at least 6' long, individual weapons, litters, lane-marking signs, gauntlets, barbed wire, stakes, and pickets.
Totals	1	5	31	

Table 10-10. Platoon Organization and Equipment for Manual Clearing

Personnel	Officer	NCO	EM	Equipment
Officer in Charge	1	---	---	Map, lensatic compass, portable radio, and all available information on mines in area.
No. 1 Clearing Party	---	1	10	Mine probes, tracing tape on reels, mine markers, grapnels, rope, or wire in 50-yard lengths. 18-in. lengths of 10- and 16-gauge wire, demolition equipment, shovels or entrenching tools, and portable radios.
No. 2 Clearing Party	---	1	10	Same as No. 1 clearing party.
No. 3 Clearing Party	---	1	10	Same as No. 1 clearing party.
Control Party	---	1	2	Map, lensatic compass, portable radio (2 preferably, 1 for platoon and for company net).
Totals	1	4	32	

Table 10-11. Clearing and Breaching Minefields with Explosive Devices

Item	M3A1	Cable, detonating, mine-clearing, AP, M 1	Bangalore torpedo
Purpose	Breach AT minefield ..	Clear narrow lane in AP minefield.	(¹)
Length	400 ft	170 ft	50 ft.
Weight	9,000 lb	63 lb	168 lb.
Weight of explosive	4,480 lb	46 lb	85 lb.
Metal used in case	Aluminum	Aluminum	Aluminum.
Crater produced:			
Length	320 ft	(²)	56 ft.
Width	4-12 ft. or more .....	.....	(³).
Depth	2-4 ft. or more .....	.....	(³).
Usual width of mine clearance accomplished ..	10-15 ft	8 ft. or less ⁴	10 ft. or less. ¹

¹ The primary purpose of the bangalore torpedo is to clear a path through wire. It will destroy or detonate most AP and AT mines within 5 ft. of it.

² No clearly defined crater. Surface soil disturbed.

³ Shallow.

⁴ Mines directly under the cable will be destroyed or detonated. Pressu re-type mines within 5 ft. of it may or may not be detonated.

Table 10-12. Typical Foreign Mines

Country	Model/type	Size (cm)	Weight (lb)	Explosive (lb) wt/type	Fuze type	Operating force (lb)
Union of Soviet Socialist Republics	POMZ-2, AP, Metal	6.0 D x 13.5 H	4.4	2.6 oz TNT	Pull	2.2
	PMK-40, AP, Cardboard	7.0 D x 3.8 H	3.2 oz.	1.8 oz TNT	Pressure	20-40
	PMD-6, AP, Wood	19 x 9 x 6.5	14 oz	7 oz TNT	Pull	2-10
	TM-41, AT, Metal	25.4 D x 14.7 H	11.9	8.4 Amatol or TNT	Pressure	440
	TMD-B, AT, Wood	32 x 28 x 14	16.1-19.8	11-15 Amatol, TNT, dynamonite, picric acid.	Pressure	440
	TMB-2, AT, Paper	27.7 D x 13.3 H	15.4	11-14.5 TNT or Amatol.	Pressure	26
	TM-46, AT, Metal	30.2 D x 7.4 H	19.2	12.6 TNT	Pressure	400
Communist China	1951, AT, Wood	33.5 x 28.4 x 14.2	18	14.5 TNT	Pressure	450
	No. 4, AT or AP, Metal	22.8 D x 10.1 H	11.4	4.5 TNT	Pressure Pull	300-500 10-50
	No. 8, AT, Metal	25 D x 15 H	12	8-9 TNT	Pressure	350
France	1951, AT, Non-metallic	30 D x 9.4 H	15.4	14.3 TNT	Pressure	660
	1951, AP, Plastic	7.1 D x 5.1 H	3 oz	1.8 oz PETN	Pressure	31-53
	1948, AT, Metal	32 D x 8.9 H	19.8	11.5 TNT	Pressure	330
	1948, AP, Bituminous	10.9 x 6.5 x 9.9	14.4 oz	6 oz Ammonium nitrate	Pressure	44
	1948, AT, Plate Charge Metal.	28 D x 13.6 H	28.5	15.2 TNT or picric acid.	Pressure offset or tilt rod.	330
	1951/55, AP, Bounding	9.9 D x 16 H	9.9 lb	14.4 oz picric acid.	Pressure	6.6
Great Britain	Mark 2, AT, Metal	25.4 D x 10.1 H	8.75	4.5 TNT	Percussion	200
	Mark 5, AT, Metal	20.3 D x 6.2 H	8.75	4.5 TNT	Percussion	250-300
	Mark 2, AP, Metal	8.8 D x 13.9 H	3 (Approx)	1 TNT	Pull	4

Section III. EXPLOSIVES AND DEMOLITIONS

10-6. General

Explosive requirements for various demolition tasks may vary widely, depending on the size of the structure, type of construction, type of materials in the structure, age, location, necessary safety precautions, and other factors. Table 10-13 shows requirements for some of the more common types of demolition tasks used for creating obstacles.

10-7. Characteristics of Explosives, Demolitions, and Firing Devices

The principal U.S. types of explosives, their characteristics and applications, are shown in table 10-14. Table 10-15 presents data on use and packing for various standard military demolition charges. Table 10-16 shows characteristics and packing of detonating cord. Table 10-17 presents data on characteristics and packing

Table 10-13. Material and Manpower Requirements for Individual Barrier Targets

Target	Material				Manpower
	TNT (lb)	Cratering charge (40 lb)	Shaped charge (40 lb)	Thermite grenades (each)	Squad hr (10 men)
Highways:					
Major bridge (over 400')	1,200				3
Minor bridge (up to 400')	800				2
Tunnels					
Road craters:	12,000				5
2-lane road (27')		7	4		2
4-lane road (70')		19	12		4
Railroads:					
Major bridge (over 400'):					
Single track	3,000				6
Double track	4,500				6
Minor bridge (up to 400')					
Single track	2,000				4
Double track	3,000				4
Tunnel	12,000				5
Terminal facilities	1,000			50	4
Rolling stock (locomotive & 30 cars)	50			125	4
Airfields:					
Runway (per 1000')	5,500		25		8
Fuel storage (per tank):					
Below ground	400			1	1
Above ground			1	1	0.2
Radar/radio apparatus	30			10	0.5
POL Facilities:					
Storage and handling	50	15		10	1
Refining facilities	100			15	1
Distributing facilities	20			2	0.2
Electric Power Denial:					
Generator	150			10	1
Transformer station	100			25	1
Telecommunications Denial:					
Telegraph exchange	25			1	0.1
Telephone exchange	25			2	0.2
Repeater/radio station	50			2	0.2
Waterways Denial:					
Lock	200				1
Wier	1,000				2
Levee wall		15	10		2
Dam (navigational)	1,000				2.5

Note. a. For classification data, see FM 101-10-3, paragraph 4-8.

b. This table is intended as a guide for planning purposes only. It should not be used as a basis for specific target material requirements.

Table 10-14. Characteristics of Principal U. S. Explosives

Name	Principal use	Size (in)	Weight (lb) & color	Detonating velocity (fps)	Relative effectiveness	Smallest cap required for detonation	Water resistance	Booster
TNT	Main charge, booster charge, cutting and breaching charge, general and military use in forward areas.	D 1½, L 3½ 3¾ x 1¾ x 1¾ 7 x 1¾ x 1¾	¼, OD ½, OD or yellow. 1, OD	23,000	1.0	Special military blasting cap, electric.	Excellent (does not readily absorb water).	N/A
Tetrytol, M1, M2		11 x 2 x 2	2½, OD	23,000	1.20		Excellent (only slightly soluble).	Tetryl pellet cast in block.
Composition C3; M3, M5.		M3-11 x 2 x 2 M5-12 x 2 x 2	2¼, OD 2½, clear plastic	26,000	1.34		Good (must be in container to prevent erosion.)	N/A
Composition C4; M5A1, M112.		M5A1-11¾ x 2 x 2 M112-11 x 2 x 1	2½, clear plastic 1¾, white	26,481 26,379	1.34		Excellent (must be kept in container to prevent erosion.)	N/A
M118 Sheet M186 Roll.	Demolition charge	Block: 12½ x 3¾ x 1¾ Sheet: 12 x 3 x ¼	2, white ½, white	23,616	1.14		Unaffected by submersion.	10 lb TNT
Ammonium nitrate	Cratering and Ditching.	D 8¾, L 17	40, OD	11,000	0.42		Poor	
Military dynamite M1	Quarry and rock cuts.	D 1¼, L 8	½, Tan	20,000	0.92		Good	N/A
Commercial Dynamite (Straight) 40%, 50%, 60%.	Land clearing, cratering, quarrying, and general use in rear areas.	D 1¼, L 8	½, Tan	40%-15,000 50%-18,000 60%-19,000	0.65 0.79 0.83	No. 6 commercial cap, electric or nonelectric.	Good (if fired within 24 hours).	N/A
Ammonia Dynamite Commercial 40%, 50%, 60%.		D 1¼, L 8	½, Tan	40%- 8,900 50%-11,000 60%-12,000	0.41 0.46 0.53		Poor	N/A
Gelatin Dynamite Commercial 40%, 50%, 60%.		D 1¼, L 8	½, Tan	40%- 7,900 50%- 8,900 60%-16,000	0.42 0.47 0.76		Good	N/A
Ammonia-Gelatin Dynamite 40%, 60%.		D 1¼, L 8	½, Tan	40%-16,000 60%-18,700			Excellent	N/A
PETN	Detonating cord	D 0.210 to 0.235	N/A, white	24,000	1.66	Special military	Good	N/A

	Blasting caps.					blasting cap, electric, non- electric.		
						N/A		
Tetryl	Booster charge	Varies	Varies, white	21,000	1.25	Special military blasting cap, electric or nonelectric.	Excellent	N/A
Composition B	Shaped charges	Varies	M2A3-12, M3-30.	23,400	1.25		Excellent	N/A
Amatol 80/20	Bangalore torpedoes	2½ x 60 (torpedo)	9 lb each torpedo.	16,000	1.17		Poor	N/A
Blackpowder	Time blasting fuze	50 ft coils	N/A, Black	1,312	0.55	N/A	Poor	N/A

fps = feet per second
 N/A = not applicable
 D = diameter
 L = length

of electric blasting caps. Nonelectric blasting cap characteristics and packing data are shown in table 10-18. Time blasting fuze and igniter data are presented in tables 10-19 and 10-20 respec-

tively. Characteristics and data on firing devices and detonators are shown in tables 10-21 and 10-22 respectively. Table 10-23 shows components of common explosive systems.

Table 10-15. Demolition Charges and Containers

Nomenclature	Uses	Packing				
		Description	Length (in)	Width (in)	Height (in)	Weight (lb)
CHARGE, DEMOLITION: block M2 (2 1/2-lb., 75-25 tetrytol).	General demolitions cutting, breaching.	8/haversack, 2 haversack (16 chg)/wdn bx.	21 1/8	14 3/8	7 3/8	56.9
CHARGE, DEMOLITION: block M3 (2 1/4-lb., comp C-2).	General demolitions cutting, breaching.	8/haversack, 2 haversack (16 chg)/wdn bx.	13 1/2	10	10 1/4	44.2
CHARGE, DEMOLITION: block M3 (2 1/4-lb., comp C-3).	General demolitions cutting, breaching.	8/haversack, 2 haversack (16 chg)/wdn bx.	13 1/2	10	10 1/4	44.2
CHARGE, DEMOLITION: block M5 (2 1/2-lb., comp C-3).	General demolitions cutting, breaching.	1/polyethylene bag, 24 bag (24 chg)/wdn bx.	17 5/8	13 7/8	12	79.6
CHARGE, DEMOLITION: block M5A1 (2 1/2-lb., comp C-4).	General demolitions cutting, breaching.	1/polyethylene bag, 24 bag (24 chg)/wdn bx.	17 3/8	13 3/4	12	80.0
CHARGE, DEMOLITION: block (1/4-lb., TNT).	General demolitions cutting, breaching.	200/wdn bx -----	18	16 1/8	10 1/2	79.0
CHARGE, DEMOLITION: block (1/2-lb., TNT).	General demolitions cutting, breaching.	100/wdn bx -----	23 3/4	11	9 1/4	69.0
		108/wdn bx -----	17 3/4	12	9	65.0
CHARGE, DEMOLITION: block (1-lb., TNT).	General demolitions cutting, breaching.	50/wdn bx -----	-----	-----	-----	63.7
		56/wdn bx -----	18 1/2	9 1/2	14 7/8	81.0
CHARGE, DEMOLITION: M112 (Comp C-4).	General demolitions cutting, breaching.	30/wdn bx -----	14	11 1/2	18 19/32	48
CHARGE, DEMOLITION: M118.	General demolitions cutting, breaching.	20/wdn bx -----	15 1/2	13 3/8	7 5/8	52
CHARGE, DEMOLITION: Roll: M186.	General demolitions cutting, breaching.	3/wdn bx -----	20	19 9/16	16 9/32	115
CHARGE, DEMOLITION: block ammonium nitrate, 40-lb (cratering).	Ditching and cratering.	1/mtl entr, 1 entr (1 chg)/wdn bx.	27 1/2	8 7/8	9 3/4	52.0
CHARGE, DEMOLITION: block ammonium nitrate, 40-lb (cratering).	Ditching and cratering.	1/wtrpf-papr bag/wdn bx --	22 1/2	9 1/2	9 3/4	50.8
CHARGE, DEMOLITION: linear (component of DEMOLITION KIT, PROJECTED CHARGE, M2).	Mine clearing breaching obstacles.	As required -----	-----	-----	-----	-----

Table 10-15. Demolition Charges and Containers—Continued

Nomenclature	Uses	Packing				
		Description	Length (in)	Width (in)	Height (in)	Weight (lb)
CHARGE, DEMOLITION: linear (Component of DEMOLITION KIT, PROJECTED CHARGE, M2A1, M3).	Mine clearing breaching obstacles.	2/wdn bx -----	63 1/4	9 1/2	7 7/8	111
CHARGE, DEMOLITION: linear (Component of EXPLOSIVE KIT, Earth Rod).	Springing charge ---	20/wdn bx -----	38 3/4	7 7/8	5 1/4	40.0
CHARGE, DEMOLITION: Shaped 15-lb., M2A3.	Penetrating steel plate, concrete, ice.	3 chg/wdn bx ----- 4/fbr cntr, 1 cntr (4 chg)/wdn bx. 4/ctn, 2 ctn (8 chg)/ wdn bx.	33 1/8	9 1/2	10 3/8	66.0
CHARGE, DEMOLITION: shaped, 15-lb., M2A4.	Penetrating steel plate, concrete, ice.	3/ctn, 1 ctn/wtrprf bag, 1 wtrprf bag (3 chg)/wdn bx.	33 15/16	9 13/16	10 19/32	65.0
CHARGE, DEMOLITION: shaped 40-lb., M3.	Penetrating steel plate, concrete, ice.	1 chg/wdn bx -----	20 1/2	11 3/4	13 3/8	65.0
CHARGE, DEMOLITION: shaped, 40-lb., M3A1.	Penetrating steel plate, concrete, ice.	1 chg/wdn bx -----	20 1/2	11 3/4	13 3/8	65.0
CHARGE, DEMOLITION, INERT: block, M4 (1/2-lb., Comp C-3).	Training -----	Packed as required -----	-----	-----	-----	-----
CHARGE, DEMOLITION, INERT: block, 2 1/2-lb., M5 (T1).	Training -----	Packed as required -----	-----	-----	-----	-----
CHARGE, DEMOLITION, INERT: block, 1-lb., (TNT).	Training -----	Packed as required -----	-----	-----	-----	-----
CHARGE, DEMOLITION, INERT: chain, M1 (eight 2 1/2-lb inert blocks.	Training -----	Packed as required -----	-----	-----	-----	-----
CHARGE, DEMOLITION, INERT: shaped, 15-lb., M233.	Training -----	Packed as required -----	-----	-----	-----	-----
CHARGE, DEMOLITION, INERT: shaped, 40-lb M3.	Training -----	Packed as required -----	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 1 mod O (for shaped charge).	Opening explosive filled ordnance.	Packed as required -----	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 2 mod O (for shaped charge).	Opening explosive filled ordnance.	1. 50/wdn box ----- 2. packed as required -----	12 3/8	12 5/8	20	19.5

Table 10-15. Demolition Charge and Containers—Continued

Nomenclature	Uses	Packing				
		Description	Length (in)	Width (in)	Height (in)	Weight (lb)
CONTAINER, DEMOLITION CHARGE: MK 3 mod 0 (for shaped charge).	Opening explosive filled ordnance.	1. 50/egg cr. 2 cr (100 cntr) crdbd ctn. 2. packed as required -----	17 5/8	17 3/8	19 1/8	48.0
CONTAINER, DEMOLITION CHARGE: MK 7 mod 1 (for shaped charge).	Opening explosive filled ordnance.	50/egg cr, 2 cr (100 cntr)/ fbrbd ctn.	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 7 mod 2 (for shaped charge).	Opening explosive filled ordnance.	50/egg cr, 2 cr (100 cntr)/ fbrbd ctn.	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 7 mod 3 (for shaped charge).	Opening explosive filled ordnance.	50/egg cr, 2 cr (100 cntr)/ fbrbd ctn.	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 7 mod 4 (for shaped charge).	Opening explosive filled ordnance.	50/egg cr, 2 cr (100 cntr)/ fbrbd ctn.	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 7 mod 5 (for shaped charge).	Opening explosive filled ordnance.	Packed as required -----	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 7 mod 6 (for shaped charge).	Opening explosive filled ordnance.	Packed as required -----	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 7 mod 7 (for shaped charge).	Opening explosive filled ordnance.	Packed as required -----	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 7 mod 8 (for shaped charge).	Opening explosive filled ordnance.	Packed as required -----	-----	-----	-----	-----
CONTAINER, DEMOLITION CHARGE: MK 8 mod 1 (for shaped charge).	Opening explosive filled ordnance underwater.	100/wtrprfd wrpd fbrbd ctn, 1 cntr (100 cntr)/ wdn bx.	-----	-----	-----	-----

Abbreviation:

bx ----- box (es)
 chg ----- charge
 cntr ----- container

cr ----- crate
 ctn ----- carton
 fbrbd ----- fiberboard

papr ----- paper
 wdn ----- wooden
 wtrpf ----- waterproof

Table 10-16. Detonating Cord

Nomenclature	Nom. dia. (in)	Covering	Loading	Packing				
				Description	Dimensions (inches)			Weight (lb)
					Length	Width	Height	
CORD, DETONATING: fuse, primacord (PETN) Type I*.	0.210	Cotton with wax gum composition finish.	50 grn PETN/ft.	1. 1,000 ft/spool, 1 spool (1,000 ft)/wdn bx.	10 3/8	10	10	16
				2. 100 ft/spool, 25 spool (2,500 ft)/wdn bx.	19 3/4	18 1/2	8 1/2	46
				3. 500 ft/spool, 1 spool/sealed can. 8 can (4,000 ft)/wdn bx.	30	15	14 5/8	105
				4. 500 ft/spool, 8 spool (4,000 ft)/ wdn bx.	-----	-----	-----	-----
				5. 50 ft/spool, 100 spool (5,000 ft)/wdn bx.	24	17	12	94
CORD, DETONATING: fuse, primacord (PETN) Type II*.	0.216	Double cotton with wax composition finished.	50 grn PETN/ft.	100 ft/spool, 50 spool (5,000 ft)/ wdn bx.	21	14 3/4	18 3/8	111
CORD, DETONATING: fuse, primacord (PETN) (50-ft spool (spliced)).	0.210	Cotton with wax gum composition finish.	50 grn PETN/ft.	Packed as required.	-----	-----	-----	-----
CORD, DETONATING: fuse, primacord (PETN) inert.	0.210	Cotton with wax gum composition finish.	Inert -----	Packed as required.	-----	-----	-----	-----
CORD, DETONATING: reinforced pliofilm-wrapped waterproof, Type IV**.	0.235	Textile with plastic coating.	60 grn PETN/ft.	1. 1,000 ft/spool, 1 spool/ crdbd bx. 3 bx/ wtrprf. lead foil env., 1 env. (3,000 ft)/wdn bx.	33 3/8	11 3/4	11 1/4	77
CORD, DETONATING: reinforced pliofilm-wrapped, waterproof Type IV**.	-----	-----	-----	2. 500 ft/spool, 1 spool sealed can 8 can (4,000 ft)/wdn bx.	-----	-----	-----	-----
CORD, DETONATING: reinforced, dummy.	0.235	Textile with plastic coating.	Inert -----	Packed as required.	-----	-----	-----	-----
CORD, DETONATING: waterproof, plastic outer covering (8-ft length) Type I**.	0.235	Textile with plastic coating.	60 grn PETN/ft.	200 length (1,600 ft)/wdn bx.	26 1/2	18	11	57

* Type designation in accordance with PA-PD-417, 7 May 1954.

** Type designation in accordance with MIL-C-17124A, 11 June 1959.

Abbreviations:

bx box(es)
crdbd cardboard
dia diameter

env envelope
ft foot (feet)
grn grain(s)

lb pound(s)
nom nominal
wdn wooden
wtrprf waterproof

Table 10-17. Electric Blasting Caps

Nomenclature	Lead wire characteristics	Packing				
		Description	Dimensions (inches)			Weight (lb)
			Length	Width	Height	
CAP, BLASTING: commercial, electric, No. 6, instantaneous.	Short lead, 4 ft. through 10 ft.	500/wdn bx	18	13 3/8	12	48.6
CAP, BLASTING: commercial, electric, No. 6, instantaneous.	Medium lead, 12 ft. through 40 ft.	As required				
CAP, BLASTING: commercial, electric, No. 6, instantaneous.	Long lead, 50 ft. through 100 ft.	As required				
CAP, BLASTING: commercial, electric, No. 8.	Short lead, 4 ft. through 10 ft.	1. 70/ctn. 5 ctn (350 cap)/wdn bx.	15	12 1/2	6 1/2	222
CAP, BLASTING: commercial, electric, No. 8, instantaneous.	Medium lead, 12 ft. through 40 ft.	As required				
CAP, BLASTING: commercial, electric, No. 8, instantaneous.	Long lead, 50 ft. through 100 ft.	As required				
CAP, BLASTING: electric, No. 8, strength.	Lead 6 ft. long, copper tinned.	50/ctn				
CAP, BLASTING: electric, No. 8, strength.	Lead 6 ft. long	70/ctn	13 3/4	7 1/4	4 3/4	8
CAP, BLASTING: electric, No. 8, strength.	Lead 30 ft. long., copper tinned.	25/ctn				
CAP, BLASTING: electric, No. 8, 1st delay (approx. 1.00 sec).	Lead 12 ft. long	500/wdn bx	19 1/2	13 1/2	9 1/4	30
CAP, BLASTING: electric, No. 8, 2nd delay (approx. 1.18 sec).	Lead 12 ft. long	500/wdn bx	19 1/2	13 1/2	9 1/4	30
CAP, BLASTING: electric, No. 8, 3rd delay (approx. 1.35 sec).	Lead 12 ft. long	500/wdn bx	19 1/2	13 1/2	9 1/4	30.5
CAP, BLASTING: electric, No. 8, 4th delay (approx. 1.53 sec).	Lead 12 ft. long	500/wdn bx	19 1/2	13 1/2	9 1/4	30.0
CAP, BLASTING: electric, high strength.	Lead 6 ft. long, copper tinned.	1. 50/ctn	9	4 1/8	3	2.34
		2. 70/ctn	14 1/2	7 1/8	3 3/4	8.0
CAP, BLASTING: electric, high strength.	Lead 9 ft. long, copper tinned.	50/ctn	7 1/4	4 3/8	3 3/4	4.0
CAP, BLASTING: electric, low strength.	Lead 6 ft. long, copper tinned.	50/ctn	6 1/2	6	2 3/4	2.0
CAP, BLASTING: electric, inert.	Various long lead wires	As required				
CAP, BLASTING: special, electric, M6.	Lead 12 ft. long, copper tinned.	1/crdbd spool, 6 spool/ctn, 1 ctn/water-prf bg, 25 bg/fbrbd bx, 6 fbrbd bx (900 cap).				

Abbreviations:

bg bag(s)
 bx box(es)
 chipbd chipboard

crdbd cardboard
 ctn carton(s)

fbrbd fiberboard
 ft foot (feet)
 lb pound(s)

Table 10-18. Nonelectric Blasting Caps

Nomenclature	Packing				
	Description	Dimensions (inches)			Weight (lb)
		Length	Width	Height	
CAP, BLASTING: nonelectric, No. 6, instantaneous.	1. 5,000/wdn bx 2. 100/ctn, 10 ctn/fbrbd bx, 1 bx/wtrprf bag, 5 bag (5,000 cap)/wdn bx.	20 1/8	9 7/8	8 3/4	29
CAP, BLASTING: nonelectric, No. 8 instantaneous.	1. 100/ctn, 50 ctn (5,000 cap)/wdn bx 2. As required	18 1/2	13	7 3/4	50
CAP, BLASTING: special nonelectric, M7	6/pprbd ctn, 1 ctn/wtrpf bag, 50 bag/fbrbd bx, 12 bx (3,600 cap)/wdn bx.				
CAP, BLASTING: tetryl, nonelectric, type A.	100/ctn, 50 ctn (5,000 cap)/wdn bx	19	16	8	65
CAP, BLASTING: nonelectric, inert	As required				

Abbreviations:

bx	box(es)	fbrbd	fiberboard	pprbd	paperboard
crdbd	cardboard	lb	pound	wdn	wooden
ctn	carton	mtl	metal	wtrprf	waterproof
		pkg	package(s)		

10-8. Calculation of Charges

The critical factors in demolition are the type of explosive used and the size, placement, and tamping of the charge. Calculation of the required amount of explosive for demolition work may be quickly accomplished by the use of a formula. In this formula, the value obtained for P represents the amount of TNT (in pounds) re-

quired for a particular charge. When other explosives are used, the value of P must be adjusted. This is done by dividing the P value obtained for TNT by the relative effectiveness factor for the explosive being used. Table 10-14 includes the relative effectiveness factors for common U.S. explosives and table 10-24 shows the formulas used for charge calculations. Table 10-25 shows

Table 10-19. Time Blasting Fuse

Nomenclature	Means of initiation	Uses	Packing			
			Description	Dimensions (inches)		
				Length	Width	Height
FUSE, BLASTING, TIME: safety fuse.	Match; fuse igniter.	Fire blasting caps, fire black blasting or pellet powder.	1. 50 ft/coil, 2 coil/pkg, 30 pkg (3,000 ft)/ wdn bx. 2. 50 ft/coil, 2 coil/pkg., 5 pkg/sealed mtl can, 8 can (4,000 ft)/wdn bx. 3. 50 ft/coil, 2 coil/pkg. 60 pkg (6,000 ft)/ wdn bx. 4. Packed as required.	24 3/4 30 29	15 3/4 14 5/8 22	12 1/2 14 5/8 17
FUSE, BLASTING, TIME: inert safety fuse.	Non-initiable	Training in use of time blasting fuse.	Packed as required			
FUSE, BLASTING, TIME: M700.	Match; fuse igniter.	Fire blasting caps, fire black blasting or pellet powder.	50 ft/coil, 2 coil/pkg, 5 pkg/ sealed container, (4,000) ft/ wdn bx.	30 3/4	15 3/4	14 5/8

Abbreviations:

ft	box(es)	lb	pound(s)	pkg	package(s)
bx	foot (feet)	mtl	metal	wdn	wooden

Table 10-20. Time Blasting Fuse Igniters

Nomenclature	Initiating action	Packing				
		Description	Dimensions (inches)			Weight (lb)
			Length	Width	Height	
IGNITER, TIME BLASTING FUSE: M1, friction.	Pulling handle to draw coated wire through friction powder.	10/wxd crdbd cntr., 250 cntr. (2,500 igniter)/wdn bx.	31½	18½	10	62.5
IGNITER, TIME BLASTING FUSE: M2, weatherproof.	Pulling release pin ring releases firing pin which strikes percussion primer.	1. 5/wtrprf ctn. 30 ctn (150 igniter)/wdn bx.	17½	9½	7¼	28.6
		2. 5/set up bx, 5 bx/ wtrprf fbrbd ctn. 10 ctn (250 igniter)/ wdn bx.	22½	12½	8	46.9
IGNITER, TIME BLASTING FUSE: M 60 (T2), weatherproof.	Pulling pull ring releases firing pin which strikes percussion primer.	5/wtprf wrppd ctn. 60 ctn (300 igniter)/ wdn bx.	21½	11½	13½	56.3
IGNITER, TIME BLASTING FUSE: M2, weatherproof, inert.	Pulling release pin ring releases firing pin which strikes dummy primer.	Packed as required				

Abbreviations:

bx	box (es)	ctn	carton (s)	wrppd	wrapped
cntr	container (s)	fbrbd	fiberboard	wtrprf	waterproof
crdbd	cardboard	lb	pound (s)	wxd	waxed
		wdn	wooden		

Table 10-21. Firing Devices and Components

Nomenclature	Initiating action	Uses	Packing				
			Description	Dimensions (inches)			Weight (lb)
				Length	Width	Height	
FIRING DEVICE, DEMOLITION: M1, 10-min. delay, black.	Finger pinch	To provide delay action firing of mines, demolition blocks and other explosive charges.	1. 10/paprbd bx, 10 bx (100 device) wdn bx.	17½	6½	4½	10.7
			2. 10/paprbd bx, 32 bx (320 device)/wdn bx.				
			3. 10/paprbd bx, 10 bx/fbrbd, 5 bx (500 device) wdn bx.	21¾	12½	11	55
FIRING DEVICE, DEMOLITION: M1, 15-min delay, red.	Finger pinch	To provide delay action firing of mines, demolition blocks and other explosive charges.	10/ctn, 12 ctn (120 device) wtrprf wdn bx, M12.	14¾	10¾	7¾	19.7
FIRING DEVICE, DEMOLITION: M1, 1 hour delay, white.							
FIRING DEVICE, DEMOLITION: M1, 2-½ hour delay, green.							
FIRING DEVICE, DEMOLITION: M1, 5-½ hour delay, yellow.							
FIRING DEVICE, DEMOLITION: M1, 11-½ hour delay, blue.							
FIRING DEVICE SET, DEMOLITION: M1 delay type.			1 set/paprbd bx, 10 bx/fbrbd bx, 5 lbs (50 set)/ wdn bx.	21¾	12¾	11	55

Table 10-21. Firing Devices and Components—Continued

Nomenclature	Initiating action	Uses	Packing				
			Description	Dimensions (inches)			Weight (lb)
				Length	Width	Height	
FIRING DEVICE, DEMOLITION: M1, pressure type.	20-lb press	Mines and boobytraps.	5/crdbd bx, 30 bx/ wtpf-wxd cloth- paper (150 de- vice) wdn bx.	40¾	10½	7¾	78
FIRING DEVICE, DEMOLITION: M1A1, pressure type.	20-lb press	Mines and boobytraps.	1. 5/bx, 50 bx (250 device) wdn bx.	27¾	12¾	10¼	80.0
			2. Packed as req'd.	-----	-----	-----	-----
FIRING DEVICE, DEMOLITION: M1A1, pressure type, inert.	Inert, non- initiable.	Training -----	Packed as req'd ..	-----	-----	-----	-----
FIRING DEVICE, DEMOLITION: M5, pressure release type.	Removal of restraining load.	Antitank mines and boobytraps.	1. 4/paprbd bx, 5 bx/fbrbd bx, 10 bx (200 de- vice/wdn bx. 2. Packed as req'd.	19¾	11¾	9½	51.9
FIRING DEVICE DEMOLITION: M5, pressure release type, inert.	Inert, non- initiable.	Training -----	As required ----	-----	-----	-----	-----
FIRING DEVICE, DEMOLITION: M1, pull type.	3-pound pull	Anti-personnel mine M3 anti- tank mines, as improvised mines, and boobytraps.	1. 5, (w/2 spool of trip wire)/ chipbd bx, 30 bx (150 device and 60 spool wire)/ wdn bx.	13½	10	8½	35.0
			2. 5, 2/w spool of trip wire/ chipbd bx/ leadfoil env. 40 env (200 device w/80 spool wire)/wdn bx. 3. Packed 250/ wdn bx. 4. Packed as req'd.	21	13	11½	65.0
FIRING DEVICE, DEMOLITION: M3, pull-release type.	Release or 6-lb pull.	Antipersonnel mine M3 impro- vised mines and boobytraps.	1. 5 (w/two 80-ft spool of trip wire)/ pkg. 5 pkg/inner pkg, 6 inner pkg (150 device and 60 spool wire)/ wdn bx. 2. Packed as re- quired.	15¾	11¾	10¾	49.9
FIRING DEVICE, DEMOLITION: M3, pull-release type, inert.	Inert, non- initiable.	Training -- --	Packed as required	-----	-----	-----	-----

Table 10-21. Firing Devices and Components—Continued

Nomenclature	Initiating action	Uses	Packing				
			Description	Dimensions (inches)			Weight (lb)
				Length	Width	Height	
FIRING DEVICE, DEMOLITION: M1, release type.	Removal of restraining load.	Boobytraps	4/chipbd bx, 20 bx (80 device)/wdn bx.	26 1/4	10 1/2	8 1/2	44.1
BASE, COUPLING, FIRING DEVICE: (w/primer percussion, M27).	-----	Component for demolition firing devices.	50/wtrprf ctn, 10 ctn (500 base)/wdn bx.	15 1/2	13 3/4	10	34.4
PRIMER, PERCUSSION: CAP, M2.	Release of firing pin.	For coupling of demolition firing device.	1. 2,500/wdn bx.	15 1/8	13 3/4	11 1/8	18.5
			2. 100/crdbd bx, 50 bx (5,000 primers)/crdbd bx (w/excelsior inside)/wdn bx.	15 5/8	9 3/4	7 1/2	24.0
PRIMER, PERCUSSION: CAP, Improved No. 3 (or equal).	Release firing pin.	For coupling base of demolition firing.	1. 100/ctn, 50 ctn (5,000 primers)/wdn bx.	19	10	8	24.0
			2. 10,000/wdn bx.	14 1/4	10 1/8	7 7/8	39.0

Abbreviations:

bx	box (es)	fbrbd	fiberboard	w/	with
chipbd	chipboard	lb	pound (s)	wdn	wooden
crdbd	cardboard	paprbd	paperboard	wtrprf	waterproof
ctn	carton (s)	pkg	package (s)	wxd	waxed
env	envelope	req'd	required		

Table 10-22. Detonators

Nomenclature	Initiating action	Operation	Delay data	Packing				
				Description	Dimensions (inches)			Weight (lb)
					Length	Width	Height	
DETONATOR, FRICTION: M1 or M1A1*, 15-sec delay. DETONATOR, FRICTION: M2, 8-sec delay.	Pulling friction material coated wire through flash compound.	1. Flash compound ignites delay fuse. 2. Delay fuse fires blasting cap.	1. Temperature/Time delay 8-sec. delay det. <i>Degrees F</i> 140—7.8 to 9.1 sec— 100—8.6 to 9.6 sec— 60—9.5 to 10.2 sec— 20—10.4 to 11.2 sec— -40—9.6 to 11.0 sec— 2. Temperature/time delay 15-sec delay det. <i>Degrees F</i> 140—13.1 to 14.0 sec— 100—14.2 to 15.0 sec— 60—15.3 to 17.1 sec—	10 pkg, 5 pkg/inner pkg, 4 pkg (200 detonator)/wdn bx.	26 1/4	11 3/4	12	M1=56.0 M2=53.9

See note below table.

Table 10-22. Detonators—Continued

Nomenclature	Initiating action	Operation	Delay data	Packing				
				Description	Dimensions (inches)			Weight (lb)
					Length	Width	Height	
			20—16.0 to 18.0 sec— —40—17.5 to 19.5 sec—					
DETONATOR, FRICTION: M1A1, 15-sec delay, inert. DETONATOR, FRICTION: M2 8-sec delay, inert.	See service counterpart above.	See service counterpart above.	Inert -----	1/mtl cntr.	-----	-----	-----	-----
DETONATOR, PERCUS- SION: M1A2 (M1E1), 15-sec delay. DETONATOR, PERCUS- SION: M2A1 (M2E1), 8-sec delay.	Removal of safeties re- leases firing pin.	1. Firing pin fires percus- sion primer. 2. Percussion primer fires delay fuse. 3. Delay fuse fires blast- ing cap.	1. 8-sec and 15-sec nominal delay. 2. Above 60° F actual de- lay will be less than nominal. 3. Below 60° F actual de- lay will be greater than nomi- nal.	25/ctn, 8 ctn (200 detonator)/ wdn bx.	24½	13	11	75.0
DETONATOR KIT, CON- CUSSION: M1.	Concussion wave from nearby blast causes re- lease of fir- ing pin. (In water firing pin is re- tained until delay tablet dissolves).	1. Firing pin fires percus- sion primer. 2. Percussion primer fires blasting cap.	1. In air: no delay. 2. In water: yellow tab- let, approx 3-½ min; blue tablet, approx 7 min.	1/mtl cntr 5 cntr (50 deto- nator)/ wdn bx.	21¼	19½	13	71.0
DETONATOR KIT, CON- CUSSION: M1 inert.	See service counterpart above.	See service counterpart above.	See service counterpart above.	As required ..	-----	-----	-----	-----

* Models M1 and M1A1 are identical in construction and use.

Abbreviations:

bx	box(es)	lb	pound(s)	pkg	package(s)
cntr	container(s)	min	minute(s)	sec	second
ctn	carton(s)	mtl	metal	wdn	wooden
det	detonator				

Table 10-23. Components of Common Explosive Systems

Demolition explosive	Priming means	Initiating means	
CORD, DETONATION ² DYNAMITE: ammonia, straight, 40% DYNAMITE: gelatin, 40%, 60%, 75% DYNAMITE: military, M1,	CAP, BLASTING: electric No. 6, No. 8, or special electric.	ELECTRIC CURRENT	
	CAP, BLASTING: nonelectric, No. 6, No. 8 or special nonelectric.	FUSE, BLASTING, TIME:	MATCH IGNITER, TIME BLASTING FUSE:
CHARGE, DEMOLITION: block, M2 ¹ CHARGE, DEMOLITION: block, M3 (COMP C-2). CHARGE, DEMOLITION: block, M3 (COMP C-3). CHARGE, DEMOLITION: block, M5 (COMP C-3). CHARGE, DEMOLITION: block, M5A1, (COMP C-4). CHARGE, DEMOLITION: block, TNT ¹ .	CAP, BLASTING: special, electric.	ELECTRIC CURRENT	
	CAP, BLASTING: special, non- electric.	FUSE, BLASTING, TIME:	MATCH IGNITER, TIME BLASTING FUSE: any.
CHARGE, DEMOLITION: block, 40 lb.	CAP, BLASTING: special, non- electric.	FUSE, BLASTING, TIME:	MATCH IGNITER, TIME, BLASTING, FUSE
	CAP, BLASTING: special electric.	ELECTRIC CURRENT	
	CORD, DETONAT- ING: fuse, prima- cord.	CAP, BLASTING: electric.	ELECTRIC CURRENT.
		CAP, BLASTING: nonelectric.	FUSE, BLASTING, TIME: and MATCH or IGNITER.
CHARGE, DEMOLITION: shaped, 15 lb, M2A3 ¹ . CHARGE, DEMOLITION: shaped, 40 lb, M3 ¹ .	CAP, BLASTING: special, electric.	ELECTRIC CURRENT	
	CAP, BLASTING: special non- electric.	FUSE, BLASTING, TIME:	MATCH IGNITER, TIME, BLASTING, FUSE
DEMOLITION KIT, BANGALORE TORPEDO: M1A1.	CAP, BLASTING: special, non- electric with CORD, DETO- NATING.	CAP, BLASTING: electric.	ELECTRIC CURRENT.
		CAP, BLASTING: nonelectric.	FUSE, BLASTING, TIME: and MATCH or IGNITER.

¹ ADAPTER, priming M1A4 may be used with electric blasting caps, which have lead wires, or with safety fuse or detonating cord with non-electric blasting caps, and is intended for use with demolition items having firing device wells which have 9/16-inch threads.

² CORD, DETONATING, may be used with adapter M1A4, and a nonelectric blasting cap, or may be wrapped around a demolition charge (except shaped charges).

the values of material factor K and figure 10-2 shows values of C (tamping factor) for use in calculations for breaching charges. Figure 10-3 shows typical charge placements.

10-9. Boobytraps

A boobytrap usually consists of a firing device with a blasting cap attached and an explosive charge. The explosive charge may be an artil-

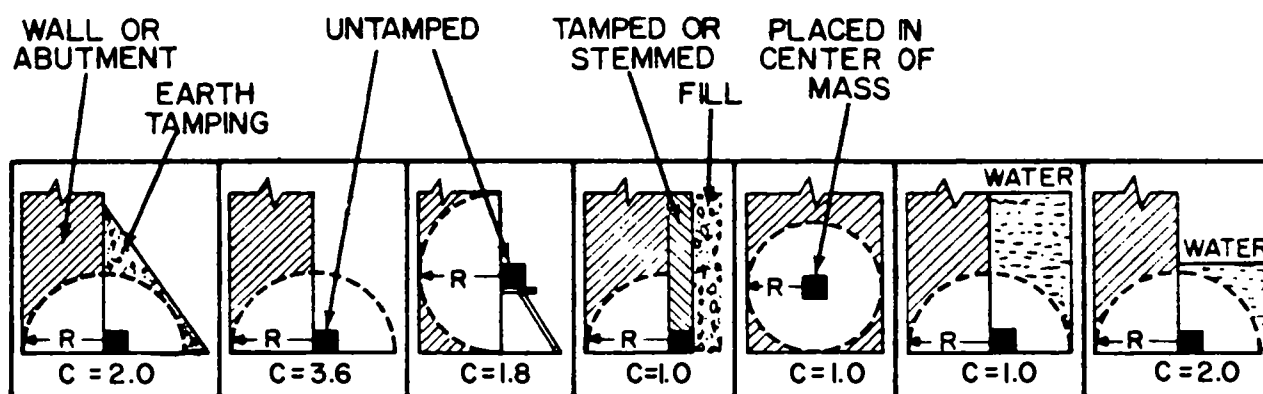


Figure 10-2. Values of C (tamping factor) for breaching charges.

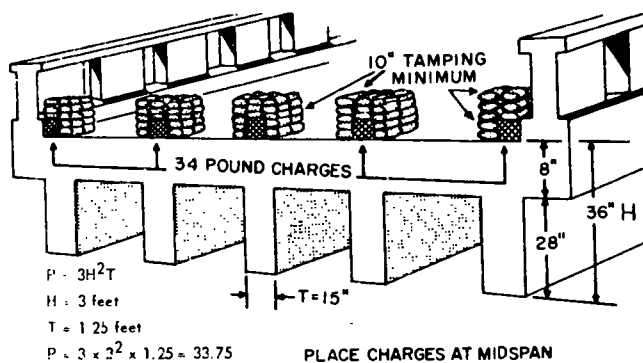
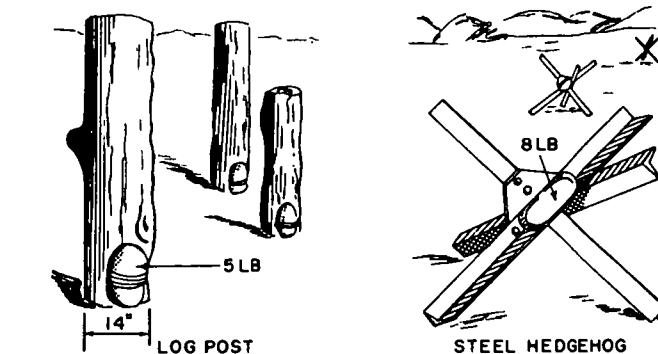
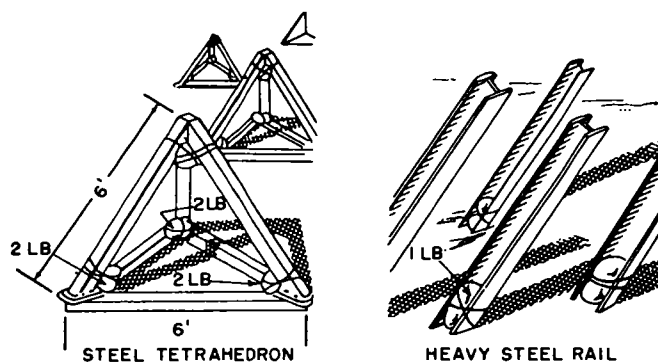
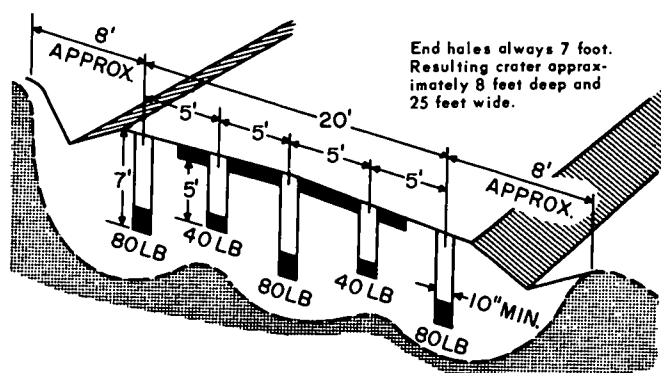
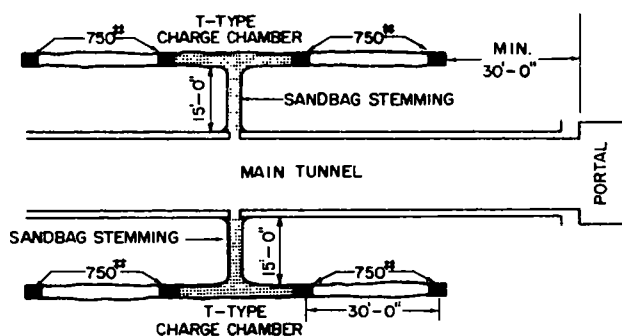
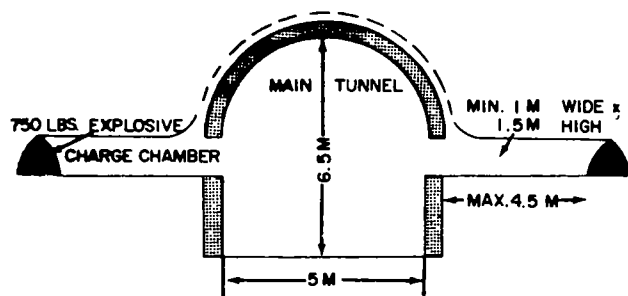
**(A) Calculation and placement of pressure charges.****(C) Placement of charges for deliberate road crater.****(B) Placement of charges for destruction of steel and log obstacles.****(D) Deliberate tunnel charge placement.****(E) Deliberate tunnel charge placement.**

Figure 10-3. Typical charge placements.

Table 10-24. Formulas for Charge Calculations *

Steel cutting charges	a. Structural steel sections: $P = \frac{3}{8}A$ (I-beams, girders, plates, etc.)	Where: P = lb TNT required A = Cross sectional area (sq in) D = Diameter (in) H = Height (ft) T = Thickness (ft) R = Breaching radius K = Material factor which indicates strength and hardness of material (see table 10-25) C = Tamping factor (see figure 10-2) N = Number of charges
	b. Other steel structures: $P = D^2$ (chairs, cables, forgings, etc.)	
	c. Railroad rails: Rule of thumb—use $\frac{1}{2}$ lb TNT for rails 5" high; 1 lb TNT for rails 5" high.	
Timber cutting charges **	a. Untamped external charges: $P = \frac{D^2}{40}$	
	b. Tamped internal charges: $P = \frac{D^2}{250}$	
	c. Tree cutting to create obstacles: $P = \frac{D^2}{50}$	
Pressure charges	a. Tamped charges: $P = 3H^2T$ (reinforced concrete T-beam bridge)	
	b. Untamped charges: Rule of thumb—increase P by $\frac{1}{3}$ of tamped charge value.	
Breaching charges	a. Breaching formula: $P = R^2KC$ (bridge piers, abutments, etc.)	
	b. Number of charges: $N = \frac{W}{2R}$	
Cratering charges	a. Deliberate method: 40 lb w/5 ft boreholes alternated with 80 lb w/7 ft boreholes placed at 5 ft intervals. All end holes must be 7 ft deep.	
	b. Hasty method: 10 lb/ft w/5 ft boreholes at 5 ft intervals.	

*These formulas are for use in calculation of initial requirements, consult FM 5-25 for further details on how the charges should be placed for various demolition targets.

** D = Diameter or least dimension.

Table 10-25. Values of Material Factor K for Use in Calculating Breaching ChargesFormula ($P(\text{TNT}) = R^2KC$)

VALUES OF K		
Material	R	K
Earth	All values	0.07
Poor masonry, shale, hardpan good timber and earth construction	Less than 5 ft	0.32
	5 ft or more	0.29
Good masonry concrete block rock	1 ft or less	0.88
	Over 1 ft to less than 3 ft	0.48
	3 ft to less than 5 ft	0.40
	5 ft to less than 7 ft	0.32
	7 ft or more	0.27
Dense concrete, first class masonry	1 ft or less	1.14
	Over 1 ft to less than 3 ft	0.62
	3 ft to less than 5 ft	0.52
	5 ft to less than 7 ft	0.41
	7 ft or more	0.35
Reinforced concrete (Concrete only, will not cut reinforcing steel)	1 ft or less	1.75
	Over 1 ft to less than 3 ft	0.96
	3 ft to less than 5 ft	0.60
	5 ft to less than 7 ft	0.63
	7 ft or more	0.54

Note. Distance (in feet) from the explosive, within which all material is displaced or destroyed. For external charges, the thickness of the mass to be breached may be taken. For internal charges, take one-half of thickness of mass to be breached if charge is placed midway into mass. If holes are drilled less than halfway into mass, the breaching radius is the longer distance from center of drill hole to outside of mass, e.g., to breach 4-foot wall by internal charge placed 1 foot into mass; breaching radius is 3 feet.

lery shell, a bomb, a landmine, or one of the explosives discussed in this section. For detailed information on tactical employment of booby-traps see FM 5-31.

10-10. Safe Handling, Transportation, and Storage

a. Safety rules regarding explosives, caps, and demolition equipment will be adhered to strictly at all times. Only during actual combat can these rules be altered to allow accomplishment of the mission. Table 10-26 shows minimum safe distances at which persons in the open are safe from bare charges placed on or in the ground.

b. Transportation of explosives for immediate use is directed by AR 385-63. The Department of the Army clearly defines the safety responsibilities of transportation officers at their installations. Local SOPs are provided to insure that all persons participating in the transportation of explosives have proper instruction in safety requirements and are held to account for all violations of procedure.

c. Explosives are stored in magazines according to safety regulations prescribed in TM 1300-206.

d. Accessibility, safety, dryness, and good drainage determine the magazine location. When magazines are not isolated, or where they are built in groups, each magazine should be surrounded with breastworks or baffle walls to minimize damage to adjacent structures in case of an explosion, and to protect magazines from bomb and shell fragments. Table 10-27 indicates the minimum distance for the location of magazines

Table 10-26. Minimum Safe Distances From Explosives for Persons in the Open

Pounds of explosive	Safe distance in meters	Pounds of explosive	Safe distance in meters
1 to 27	300	80	431
28	304	85	440
29	308	90	449
30	311	95	457
32	318	100	465
34	324	125	500
36	331	150	534
38	337	175	560
40	342	200	585
42	348	225	609
44	353	250	630
46	359	275	651
48	364	300	670
50	369	325	688
55	381	350	705
60	392	375	722
65	402	400	737
70	413	425 and over	750
75	422		

Notes. 1. For charges less than 28 pounds, the minimum safe distance is 300 meters. This, however, gives no insurance against missile hazards, which require a defilade.

2. For charges from 28 to 425 pounds, the safe distance is computed by means of this formula:

$$\text{Safe distance in meters} = 100 \sqrt{\text{pounds of explosive}}$$

3. For quarrying operations the formula is:

$$\text{Safe distance in feet} = 350 \sqrt{\text{pounds of explosive}}$$

from other magazines, buildings, and routes of communication based on the quantity of Class VII materials stored.

Table 10-27. Quantity-Distance Table for Class VII Materials

(Materials packed in approved storage containers and/or cartridge cases but in unbarricaded magazine).

Quantity of explosives		Distance in feet		
Pounds (over)	Pounds (not over)	To inhabited buildings	To public railroads and public highways	To unbarricaded magazines (intraline distance)
0	50	300	180	60
50	100	380	230	80
100	500	640	380	140
500	1,000	800	480	190
1,000	2,000	1,010	610	230
2,000	4,000	1,270	760	280
4,000	6,000	1,460	880	320
6,000	8,000	1,600	960	360
8,000	10,000	1,730	1,040	400
10,000	20,000	1,950	1,170	490
20,000	40,000	2,550	1,530	620

Table 10-27. Quantity-Distance Table for Class VII Materials—Continued

Quantity of explosives		Distance in feet		
Pounds (over)	Pounds (not over)	To inhabited buildings	To public railroads and public highways	To unbarricaded magazines (intraline distance)
40,000	60,000	3,030	1,820	700
60,000	80,000	3,390	2,035	780
80,000	100,000	3,630	2,180	830
100,000	200,000	4,060	2,435	1,050
200,000	300,000	4,550	2,730	1,200
300,000	400,000	5,000	3,000	1,330
400,000	500,000	5,410	3,245	1,430

Section IV. ATOMIC DEMOLITIONS

10-11. General

Atomic demolitions munitions (ADM) may be effectively employed to create obstacles and to destroy and deny military facilities or installations. Since ADM are emplaced without delivery error, the most efficient use of nuclear energy is achieved. ADM can accomplish missions which might normally be prohibitive for conventional explosives primarily because of the logistical effort involved. The destruction of massive structures or missions that require moving large quantities of earth, such as blocking defiles or tunnels, are easily within the capability of ADM. The size of the munition makes the time, manpower, and logistical support infinitesimal compared to that required for conventional demolitions. Moreover, ADM are designed to have a subsurface capability. Hence, if burial of ADM is desired, preplanning of an employment hole must be considered, and appropriate steps taken to provide the necessary equipment and personnel.

10-12. Characteristics of ADM

Because of security considerations, data pertinent to actual stockpile ADM are not presented in this manual but are covered in FM 101-31-2. A hypothetical ADM family is used to facilitate unclassified information in ADM employment. Table 10-28 gives the models, yields, sizes, and weights of a hypothetical ADM family. Tables 10-29 and 10-30 cover fallout prediction distance, radiation exposure risks, and troop safety distances. Tables 10-31 through 10-37 cover damage and contingency effects for the hypothetical ADM family. For purposes of planning ADM missions to provide logistical support, ADM are assumed to have the following characteristics.

a. Firing Options. Once emplaced, ADM of

the hypothetical family are considered to have a remote, on-call firing capability as well as a timer option. For the purposes of selecting the firing position (command site), the emplacement position should be far enough away so that the firing party is not exposed to more than the accepted degree of risk, yet close enough that visual security of the emplacement can be maintained.

b. Subsurface Capability. ADM of the hypothetical family are assumed to have both an underground and underwater capability. Underground burial is limited to 10 meters of backfill which is tamped material replaced directly on top with no protective shielding of the ADM. Underwater detonation is possible in depths of up to 30 meters. If greater depths are desired, special adaptive devices are required to protect the munition from excessive overhead pressures.

c. Separation Distances. To insure that one emplaced ADM is not damaged by the detonation of another in the same general target area, it is assumed that for the hypothetical family a separation distance of 1,000 meters between ADM detonations on the surface is required for all yields. For subsurface bursts near optimum depths, this distance may be reduced by one-half.

d. Response Times. As a basis for general tactical planning, 2 hours is assumed to be the average time for a reasonably well-trained ADM team operating in daylight under favorable conditions to prepare and emplace a hypothetical ADM with remote options on the surface or in a previously prepared position. If only timer option is used, planning time may be reduced to 1 hour. Adverse conditions or elaborate preparations may considerably extend this period. Transportation time to the emplacement site is in addition to the above stated times.

Table 10-28. Hypothetical ADM Family

Model/yield (kt)		Cannister length		Emplacement hole diameter		Transportation weight (pounds)
		feet	meters	inches	meters	
SIERRA	/0.01	3	0.91	15	0.38	100
TANGO	/0.03	3	0.91	15	0.38	100
UNIFORM	/0.05	3	0.91	15	0.38	100
VICTOR	/0.10	3	0.91	15	0.38	100
WHISKEY	/0.30	3	0.91	15	0.38	100
ALFA	/0.50	5	1.52	30	0.76	500
BRAVO	/1	5	1.52	30	0.76	500
DELTA	/5	5	1.52	30	0.76	500
ECHO	/10	10	3.05	36	0.91	1500
GOLF	/50	10	3.05	36	0.91	1500
HOTEL	/100	10	3.05	36	0.91	1500

Table 10-29. Downwind Distances of Zones I, I-A, and II (Kilometers)

YIELD (KT)	SURFACE BURST DOB = 0			SUBSURFACE BURST DOB = 15W ^{0.3m}			OPTIMUM BURIAL DOB = 49W ^{0.3m}		
	ZONE I	ZONE I-A	ZONE II	ZONE I	ZONE I-A	ZONE II	ZONE I	ZONE I-A	ZONE II
SIERRA/0.01	.48	.79	1.1	.56	.77	.97	≤.4	≤.4	≤.4
TANGO/0.03	.71	1.3	1.8	.83	1.2	1.5	≤.4	≤.4	≤.4
UNIFORM/0.05	.94	1.7	2.5	1.1	1.7	2.2	≤.4	≤.4	≤.4
VICTOR/0.1	1.5	2.7	3.8	1.7	2.5	3.3	≤.4	0.40	0.57
WHISKEY/0.30	3.6	5.4	7.2	4.0	5.1	6.2	0.54	0.71	1.1
ALPHA/0.5	4.4	6.6	8.8	4.8	5.7	7.6	0.66	0.99	1.3
BRAVO/1.0	5.7	8.6	11.4	6.2	7.9	9.5	0.86	1.3	1.7
DELTA/5.0	12.0	18.0	24.0	12.7	16.2	19.7	1.8	2.7	3.6
ECHO/10.0	15.0	22.5	30.0	15.9	20.3	24.6	2.3	3.5	4.5
GOLF/50.0	30.0	45.0	60.0	31.5	40.1	48.6	4.5	6.8	9.0
HOTEL/100.0	39.0	58.5	78.0	40.6	51.9	63.1	5.9	8.9	11.7

Notes. An effective wind speed of 15 knots (27 Km/hr) is assumed. Downwind distances are based on fallout prediction using TM 3-210.

ZONE I. A zone within which there will be areas where exposed, unprotected personnel may receive doses greater than 50 rad (the emergency risk dose) in relatively short periods of time (less than 4 hours after arrival of fallout).

ZONE I-A. A zone within which there will be areas where exposed unprotected personnel may receive doses greater than 50 rad (the emergency risk dose) in relatively short periods of time (less than 4 hours after actual arrival of fallout).

ZONE II. A zone within which the total dose to exposed, unprotected personnel is not expected to exceed 50 rad when remaining in the area for not more than 4 hours after the actual arrival of fallout.

Table 10-30. Troop Safety Distances (Meters)*

Yield KT	Depth of burial	Minimum distance for troop vulnerability and degree of risk shown					
		Unwarned Exposed		Warned Exposed		Warned Protected	
		NEG Risk	EMER Risk	NEG Risk	EMER Risk	NEG Risk	EMER Risk
SIERRA 0.01	0	1200	800	1200	800	900	600
	2	1150	880	1150	880	900	820
	4 ^a	1100	900	1100	900	900	900
	8	940	800	940	800	820	800
	12 ^b	800	550	800	550	650	550
TANGO 0.03	0	1300	860	1250	860	1000	700
	2	1200	940	1200	940	1000	920
	5 ^a	1100	980	1100	980	980	980
	10	1000	870	1000	870	880	870
	17 ^b	810	560	810	560	660	560
UNIFORM 0.05	0	1350	900	1300	900	1100	740
	3	1250	1000	1250	1000	1100	950
	6 ^a	1150	1050	1150	1050	1050	1050
	12	1050	920	1050	920	930	920
	21 ^b	820	600	820	600	680	600
VICTOR 0.1	0	1400	950	1350	950	1200	820
	3	1400	1100	1350	1100	1200	1050
	7 ^a	1300	1200	1300	1200	1200	1200
	16	1100	1000	1100	1000	990	1000
	24 ^b	860	660	860	660	740	660
WHISKEY 0.3	0	1600	1100	1500	1100	1350	960
	5	1630	1550	1600	1550	1600	1450
	10 ^a	1650	1650	1650	1650	1650	1650
	20	1450	1450	1450	1450	1450	1450
	34 ^b	960	840	960	840	900	900
ALFA 0.5	0	1700	1200	1550	1200	1450	1050
	5	1850	1700	1800	1700	1750	1600
	12 ^a	1900	1900	1900	1900	1900	1900
	25	1600	1600	1600	1600	1600	1600
	40 ^b	1050	980	1050	980	1000	980
BRAVO 1	0	1900	1350	1650	1250	1600	1200
	5	2150	1800	2050	1750	2000	1750
	15 ^a	2300	2300	2300	2300	2300	2300
	30	2000	2000	2000	2000	2000	2000
	49 ^b	1250	1250	1250	1250	1250	1250
DELTA 5	0	2700	2100	2050	1650	1900	1500
	10	3600	3200	3150	3100	3100	3050
	24 ^a	3900	3900	3900	3900	3900	3900
	50	3400	3400	3400	3400	3400	3400
	79 ^b	2150	2150	2150	2150	2150	2150
ECHO 10	0	3600	2700	2400	1900	2100	1650
	15	4650	4250	4200	4050	4100	4000
	30 ^a	4900	4900	4900	4900	4900	4900
	60	4300	4300	4300	4300	4300	4300
	97 ^b	2700	2700	2700	2700	2700	2700
GOLF 50	0	8500	6300	4400	3700	2600	2100
	25	8700	8100	7600	6900	6400	6000
	48 ^a	8800	8800	8800	8800	8800	8800

See notes below table.

Table 10-30. Troop Safety Distances (Meters)*—Continued

Yield KT	Depth of burial	Minimum distance for troop vulnerability and degree of risk shown					
		Unwarned Exposed		Warned Exposed		Warned Protected	
		NEG Risk	EMER Risk	NEG Risk	EMER Risk	NEG Risk	EMER Risk
	100	8300	8300	8300	8300	8300	8300
	159 ^b	4800	4800	4800	4800	4800	4800
HOTEL	0	15000	10000	6500	5400	2750	2300
	30	13000	11000	10000	9300	8500	8500
100	60 ^a	11500	11500	11500	11500	11500	11500
	130	9200	9200	9200	9200	9200	9200
	195 ^b	6000	6000	6000	6000	6000	6000

* For initial effects and base surge only. A fallout prediction must be made. Based on RS-1 unit (less than 5 rad previous exposure). Underlined distances indicate that nuclear radiation is the governing safety effect. If unit is RS-2 or RS-3, any further exposure is considered an emergency risk (see FM 3-12).

^a Shallow depth of burial (table 10-33).

^b Optimum depth of burial (table 10-33).

Table 10-31. Light, Moderate, and Severe Airblast Damage Distances for Surface Bursts (Meters) ^{1,2}

Material classification		Sierra 0.01	Tango 0.03	Uniform 0.05	Victor 0.10	Whiskey 0.30	Alfa 0.50	Bravo 1	Delta 5	Echo 10	Golf 50	Hotel 100
Wheeled Military Vehicles	Mod	52	59	70	81	118	137	170	410	520	1070	1400
Railroad Cars												
Engr Truck Mounted Equip	Sev	33	41	55	67	74	93	130	240	333	666	1075
Tanks and Artillery	Mod	33	41	48	59	70	85	118	222	296	610	760
Railroad Locomotives												
Engr Earthmoving Equip	Sev	22	33	41	48	52	55	85	144	222	444	555
Communications Equip	Sev	63	70	89	118	144	170	222	463	655	1355	1775
Supply Dumps	Sev	15	18	22	26	30	44	59	115	170	348	480
Truss & Float Bridges	Mod	45	52	67	78	96	111	141	311	404	815	1070
	Sev	30	37	44	55	67	78	130	252	288	606	925
Field Fortifications	Mod	26	33	41	52	59	63	93	156	192	348	585
Earth Covered Surface Shelters	Sev	26	33	44	48	56	59	74	148	182	326	448
Monumental-Type Multistory Wall-Bearing Bldgs.	Mod	110	126	156	185	215	259	426	622	815	1330	1465
Multistory, Wall Bearing Bldgs (Apt House Type).	Sev	74	96	122	148	174	204	296	504	610	1035	1170
Multistory, Reinforced Bldgs (small window area).	Mod	48	59	74	96	122	148	259	333	480	925	1075
Multistory, Steel Frame Office Bldgs.												
Blast Resistant Reinforced Concrete Bldgs.	Sev	37	41	48	63	74	93	118	181	389	722	888
Light Steel Frame Industrial Bldgs.												
Oil Storage Tanks	Mod	167	185	211	270	315	374	474	852	1165	2120	2330
Parked Combat Aircraft	Sev	110	122	152	189	211	252	333	593	765	1385	1445
Wood Frame Bldgs.	Mod	155	178	218	248	333	370	593	892	1150	2110	2550
	Sev	104	126	144	185	222	259	510	688	881	1640	2065
All targets ³ No light damage		365	516	618	768	1120	1325	1670	2870	3620	6210	7820

¹ For subsurface bursts, see table 10-32.

² There is a 90% probability that the damage distances will be met or exceeded.

³ For no light damage, there is a 90% probability of no light damage at these distances or greater.

Table 10-32. Airblast Damage Reduction Distances, Subsurface Burst (meters)

DOB (meters)	Sierra 0.01	Tango 0.03	Uniform 0.05	Victor 0.10	Whiskey 0.30	Alfa 0.50	Bravo 1	Delta 5	Echo 10	Golf 50	Hotel 100
1	2	2	3	4	5	6	7	13	24	41	63
2	4	4	6	7	8	9	11	17	31	47	73
3	7	12	14	16	17	19	22	40	58	79	107
4	13	14	16	17	19	22	30	59	82	122	159
5	20	22	26	30	33	36	44	85	118	163	244
6	26	28	31	37	39	45	59	115	155	255	315
7	(*)	(*)	(*)	44	48	59	74	141	226	300	381
8	-----	-----	-----	(*)	63	78	96	163	308	370	440
9	-----	-----	-----	-----	(*)	107	122	204	378	433	470
10	-----	-----	-----	-----	-----	(*)	152	248	448	500	518
15	-----	-----	-----	-----	-----	-----	(*)	304	525	582	607
25	-----	-----	-----	-----	-----	-----	-----	(*)	593	658	704
40	-----	-----	-----	-----	-----	-----	-----	-----	(*)	(*)	835

Note. To determine the airblast damage distances to various material targets for subsurface detonations, the distances given in this table must be subtracted from the airblast damage distances associated with surface bursts as shown in table 10-31. Should the result be a negative number, consider that the damage radii is zero.

* No damage-producing airblast at or below this depth of burial (DOB).

Table 10-33. Crater Dimensions for Dry Soil or Soft Rock*

Model/yield (kt)	Approximate crater dimensions (meters)								
	Surface			15W ^{0.3} meters (shallow)			49W ^{0.3} meters (optimum)		
	DOB	Diameter	Depth	DOB	Diameter	Depth	DOB	Diameter	Depth
SIERRA/0.01	0	9	2	4	21	6	12	27	7
TANGO/0.03	0	12	2	5	30	8	17	37	10
UNIFORM/0.05	0	15	3	6	34	9	21	44	12
VICTOR/0.10	0	18	4	7	43	11	24	53	14
WHISKEY/0.30	0	27	5	10	60	16	34	75	20
ALFA/0.5	0	32	6	12	69	19	40	87	23
BRAVO/1	0	40	8	15	85	23	49	107	28
DELTA/5	0	68	14	24	139	37	79	173	45
ECHO/10	0	86	17	30	169	46	97	213	56
GOLF/50	0	147	30	48	274	74	159	347	91
HOTEL/100	0	185	37	60	338	91	195	426	111

* For hard rock or concrete, use a 0.8 multiplication factor.

*Table 10-34. Tree Blowdown Obstacle for Surface Burst (Meters)**

Yield KT	Obstacles to movement	
	Deciduous	Coniferous
SIERRA/0.01	70	65
TANGO/0.03	85	75
UNIFORM/0.05	95	85
VICTOR/0.1	110	100
WHISKEY/0.3	160	150
ALFA/0.5	195	175
BRAVO/1	260	250
DELTA/5	520	500
ECHO/10	790	700
GOLF/50	1555	1430
HOTEL/100	2200	2000

* These radii apply to surface bursts. For an approximation of the effect when the ADM is buried, these radii may be reduced using table 10-32.

*Table 10-35. Fire Areas for Surface Burst **

Yield KT	Expected radii for ignition of wildland fuels during fire season—meters							
	Dry climate (25 percent relative humidity)				Damp climate (75 percent relative humidity)			
	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV
SIERRA/0.01 -----	225	200	200	175	225	200	200	175
TANGO/0.03 -----	250	250	250	225	250	250	250	225
UNIFORM/0.05 -----	300	300	275	250	300	300	275	250
VICTOR/0.10 -----	375	375	325	350	375	375	325	350
WHISKEY/0.30 -----	400	400	350	350	400	400	350	350
ALFA/0.5 -----	500	500	400	400	500	500	400	400
BRAVO/1 -----	700	600	500	500	600	600	500	400
DELTA/5 -----	1,200	1,100	1,000	800	1,100	1,100	900	700
ECHO/10 -----	1,500	1,400	1,300	1,100	1,400	1,400	1,200	900
GOLF/50 -----	2,800	2,600	2,300	2,000	2,600	2,600	2,200	1,600
HOTEL/100 -----	3,500	3,200	3,000	2,500	3,200	3,200	2,800	2,100

* For description of fuel classes, see table 10-36.

Table 10-36. Forest Fuel Classes

Forest fuels	
Class	Description
I	Broadleaf and coniferous litter mixture of fine grass, broken leaves and duff, and thin translucent broad leaf leaves.
II	Hardwood and soft wood punk in various stages of decay.
III	Cured or dead grass.
IV	Conifer needles and thick nearly opaque broadleaf leaves.

Table 10-37. Light Aircraft in Flight for Surface Burst

Yield KT	Aircraft safety radii—meters*		
	Light fixed wing	Recon and obsn hel	Transport and util hel
SIERRA/0.01	1400	1500	1400
TANGO/0.03	1600	1600	1600
UNIFORM/0.05	2000	2000	1900
VICTOR/0.10	2600	2600	2500
WHISKEY/0.30	3000	3000	3000
ALFA/0.5	4000	4000	4000
BRAVO/1	5000	5000	5000
DELTA/5	9000	9000	7000
ECHO/10	10000	10000	9000
GOLF/50	17000	16000	15000
HOTEL/100	22000	21000	18000

*A buffer distance has been added to these radii of safety.

CHAPTER 11

FORTIFICATIONS AND PROTECTIVE STRUCTURES

Section I. GENERAL

11-1. References

Detailed data on field fortifications can be found in FM 5-15, FM 5-34, and FM 101-10-1. TM 5-311 covers protective structures for nuclear, chemical, and biological warfare.

11-2. Defense Frontages

Average frontages normally assigned to infantry or engineer units in defensive missions are given in table 11-1.

11-3. Field Fortifications

a. Priority of Work. The order in which the various defensive measures are to be executed is expressed in the form of priorities. The assignment of priorities does not prevent simultaneous work on several tasks. After the location of combat emplacements has been fixed, the normal priority is—

- (1) Establishing security.
- (2) Positioning weapons.
- (3) Clearing fields of fire, removing objects,

masking observation, and determining ranges to probable target location.

(4) Providing signal communication and observation systems.

(5) Preparing weapons emplacements and individual positions, to include overhead cover, and camouflaging them concurrently.

(6) Laying minefields and preparing important demolitions.

(7) Preparing routes for movement and for supply and evacuation.

(8) Preparing alternate supplementary positions.

(9) Preparing obstacles (other than minefields) and less vital demolitions.

(10) Preparing CBR protective shelters as required.

(11) Preparing deceptive installations in accordance with deception plans of higher headquarters.

b. Work. (Figures are for daylight; for work at night, increase labor by 50 percent.)

Table 11-1. Defense Frontages (Meters)

Unit	Situation	Terrain	Frontage (in meters)	
Bn	Nonnuclear	----	2,300 - 4,100	
	Nuclear	----	3,650 - 5,500	
	No mobility		6,400	
	Calculated risk		8,200	
Rifle Co	With mobility			
	All situations		Occupy	Occupy & Cover
		Close	270	450
		-- do --	540	910
1 plt		-- do --	820	1,370
2 plt		-- do --	1,090	1,820
3 plt		Open	410	730
4 plt		-- do --	820	1,460
		-- do --	1,280	2,190
		-- do --	1,640	2,740

(1) *Characteristics of personnel and individual weapons emplacements.* See table 11-2.

(2) *Characteristics of crew-served infantry and artillery weapons emplacements.* See table 11-3.

(3) *Clearing.* Four man-hours of labor are required for clearing 100 square yards of brush and a few trees up to 12 inches in diameter; for brush only, 2 man-hours.

(4) *Barbed wire obstacles, estimating requirements.* The minimum length of tactical wire entanglements for a defensive position is one and one-fourth times the frontage; minimum protective wire is five times the frontage. The length of tactical wire entanglements for a deliberate defense is five times the frontage; protective wire is six times the frontage.

(5) *Vehicle pits.* Table 11-4 shows dimensions of typical vehicle pits.

(6) *Foxhole digger explosive kit.* This kit includes shaped and cratering charges for use by the individual soldier in preparing a foxhole. When available through supply channels its use can greatly reduce manpower and manhour requirements for initial foxhole preparation. (See app D, FM 5-15 for further details.)

Table 11-2. *Characteristics of Personnel and Individual Weapons emplacements*

(Located in back of manual)

Table 11-3. *Characteristics of Crew-served Infantry and Artillery Weapons Emplacements*

(Located in back of manual)

Table 11-4. *Dimensions of Typical Vehicle Pits*

	1/4-ton truck and trailer, canvas down	3/4-ton truck and trailer, with radio shelter	2 1/2-ton truck and trailer, canvas down	5-ton truck and trailer, canvas down
Depth of cut (C)	0.9 meters (3.0 feet)	1.8 meters (5.9 feet)	1.5 meters (4.9 feet)	1.5 meters (4.9 feet)
Width of pit	2.4 meters (7.9 feet)	3.0 meters (9.8 feet)	3.5 meters (11.5 feet)	3.6 meters (11.8 feet)
Level length of pit (L)	6.0 meters (19.7 feet)	8.1 meters (26.6 feet)	10.5 meters (34.4 feet)	10.8 meters (35.4 feet)
Thickness of parapet (H) ..	60 cm (23.6 in)	75 cm (29.5 in)	75 cm (29.5 in)	75 cm (29.5 in)
Width of parapet (P)	1.2 meters (3.9 feet)	2.4 meters (7.9 feet)	2.7 meters (8.9 feet)	2.7 meters (8.9 feet)
Exit slope (A:B) *	1:1	2:1	2:1	2:1
Total excavation	19 cubic meters (24.9 cu ft)	61 cubic meters (79.8 cu ft)	71 cubic meters (92.9 cu ft)	76 cubic meters (99.4 cu ft)
Equipment hours **	0.4	0.8	0.9	0.9

*Entrance slope 1:1.

**For cut and rough parapet construction only, at appropriate rates for D7 or D8 type bulldozers.

Section II. COVER AND SHELTER

11-4. General

a. Requirements. Shelters are constructed primarily to protect troops from enemy action and the weather. They are not fighting emplacements but are often included in fighting positions. Shelters should be sited on reverse slopes, in woods, or in some form of natural defilade such as ravines, valleys, or depressions. All shelters must be camouflaged or concealed.

b. Types. Shelters are divided into two groups according to their type of construction—hasty or deliberate.

(1) Hasty shelters are normally constructed of local, expedient materials by combat troops, primarily for protection from inclement weather when on short halts and bivouacs.

(2) Deliberate shelters are constructed by supporting units in rear of frontlines for protection from artillery fire, strafing, bombing, and the weather.

(3) Shelters, whether hasty or deliberate, are further divided into three general types—

(a) Surface shelters built aboveground where ground conditions prohibit excavation.

(b) Cut-and-cover shelters partially or wholly dug into the ground and backfilled and covered with soil.

(c) Cave shelters dug laterally into reverse slopes or tunneled into flat ground.

11-5. Protection Against Conventional Weapons

a. Table 11-5 shows the thickness of various

materials required to protect against single direct hits by direct-fire weapons.

b. Table 11-6 shows the thicknesses of various materials required to protect against projectiles and bombs exploding at a distance of 50 feet.

11-6. Design Data on Overhead Cover Support Materials

Tables 11-7, 11-8, and 11-9 provide design data on materials used to support overhead cover.

Table 11-5. Material Thickness Needed for Protection Against Direct Hits by Direct-Fire Weapons

Material	Small-arms and machine-gun (7.92-mm.) fire at 100 yd. ¹ (in.)	Antitank rifle (7.92-mm.) fire at 100 yd. (in.)	20-mm. antitank fire at 200 yd. (in.)	37-mm. antitank fire at 400 yd. (in.)	50-mm. antitank fire at 400 yd. (in.)	75-mm. direct fire, 500 to 1,000 yd. (in.)	88-mm. direct fire, 500 to 1,000 yd. (in.)	Remarks
Solid walls: ²								
Brick masonry	18	24	30	60	-----	-----	-----	Plain, formed-concrete walls. Structurally reinforced. These figures can be taken as guides only.
Concrete, not reinforced. ³	12	18	24	42	48	54	78	
Concrete, reinforced	6	12	18	36	42	48	78	
Stone masonry	12	18	30	42	54	60	-----	
Wood	24	36	48	-----	-----	-----	-----	These figures can be taken as guides only.
Timber	36	60	-----	-----	-----	-----	-----	These figures can be taken as guides only.
Walls of loose material packed between boards: ²								
Brick rubble	12	24	30	60	72	-----	-----	Add 100 percent if wet. Add 50 percent if wet.
Clay, dry	36	48	-----	-----	-----	-----	-----	
Loam, dry	24	36	48	-----	-----	-----	-----	
Gravel or small crushed rock.	12	24	30	60	72	-----	-----	
Sand, dry	12	24	30	60	72	-----	-----	Add 100 percent if wet.
Sandbags, filled with:								
Brick rubble	20	30	30	60	70	-----	-----	Add 100 percent if wet. Add 50 percent if wet.
Clay, dry	40	60	-----	-----	-----	-----	-----	
Loam, dry	30	50	60	-----	-----	-----	-----	
Gravel or small crushed rock.	20	30	30	60	70	-----	-----	
Sand, dry	20	30	30	60	70	-----	-----	Add 100 percent if wet.
Loose parapets of: ²								
Clay	42	60	-----	-----	-----	-----	-----	Add 100 percent if wet.
Loam	36	48	60	-----	-----	-----	-----	Add 50 percent if wet.
Sand	24	36	48	-----	-----	-----	-----	Add 100 percent if wet.

¹ 1 burst of 5 shots.

² Thicknesses given to nearest half foot.

³ For 3,000 p.s.i. concrete.

Protective thicknesses given are for a single shot only (except ¹). Where direct-fire weapons are able to get 5 or 5 hits in the same area, the required protective thickness is approximately twice that indicated.

**Table 11-6. Material Thickness Needed for Protection Against Projectiles and Bombs
Exploding 50 Feet Away**

High-explosive shells and rockets				General-purpose bombs			
Material	75-mm. (in.)	105-mm. (in.)	155-mm. (in.)	100-lb. (in.)	250-lb. (in.)	500-lb. (in.)	1,000-lb. (in.)
Solid walls:							
Brick masonry	4	6	8	8	10	13	17
Concrete, plain	4	5	6	8	10	15	18
Concrete, reinforced	3	4	5	7	9	12	15
Timber	8	10	14	15	18	24	30
Walls of loose material between boards:							
Brick rubble	9	10	12	18	24	28	30
Gravel, small stones	9	10	12	18	24	28	30
Earth ¹	15	18	24	24	30	-----	-----
Sandbags filled with:							
Brick rubble	10	10	20	20	20	30	40
Gravel, small stones	10	10	20	20	20	30	40
Sand ¹	10	10	20	30	30	40	40
Earth ¹	20	20	30	30	40	40	50
Parapets of: ²							
Sand ¹	12	18	24	24	36	36	48
Earth ¹	24	36	48	36	48	60	-----

¹ Figures based on dry material. If wet material, double figures.

² Figures given to nearest ½ foot.

Table 11-7. Size of Roof Supports

(1) Timber sizes.

Size of timber (diameter)	Maximum span when used to support 45 cm of earth
10 cm (4 in.)	1.2 meters (4 feet)
12.5 cm (5 in.)	2.0 meters (5 feet)
15 cm (6 in.)	2.1 meters (7 feet)
17.5 cm (7 in.)	2.7 meters (9 feet)
20.0 cm (8 in.)	3.3 meters (11 feet)
22.5 cm (9 in.)	3.9 meters (13 feet)

(2) Conversion table from timbers to lumber.

Size of rectangular timber	Size of round timber required to equal (in inches)
6x6	7
6x8	8
8x8	10
8x10	11
10x10	12
10x12	13
12x12	14

Table 11-8. Thickness in Inches of Laminated Wood Required to Support Various Thicknesses of Earth Cover Over Various Spans

Thickness of earth cover in feet	Span width in feet					
	2½	3	3½	4	5	6
1½	1	1	2	2	2	2
2	1	2	2	2	2	3
2½	1	2	2	2	2	3
3	2	2	2	2	3	3
3½	2	2	2	2	3	3
4	2	2	2	2	3	4

11-7. Ice and Snow Cover

Minimum thicknesses of snow and ice for protection against small-arms fire are as follows:

New snow, 13 feet.

Tamped snow, 8 to 10 feet.

Frozen snow, 6.5 feet.

Ice, 3.25 feet.

Ice concrete, 1 to 2 feet.

Table 11-9. Center to Center Spacing, in Inches, of Wooden Stringers Required to Support a 1-Inch Thick Wood Roof with Various Thicknesses of Earth Cover Over Various Spans

Thickness of earth cover in feet	Span width in feet					
	2½	3	3½	4	5	6
1½	40	30	22	16	10	18*
2	33	22	16	12	8/20*	14*
2½	27	18	12	10	16*	10*
3	22	14	10	8/20*	14*	8*
3½	18	12	8/24*	18*	12*	8*
4	16	10	8/20*	16*	10*	7*

Stringers are 2" by 4" except those marked by an asterisk () which are 2" by 6".

11-8. Ice Concrete

Ice concrete is a dense frozen mixture of sand and water, or sand with gravel and crushed rock and water. At least 10 percent of the mixture should be sand and only enough water should be

added to the mixture to make it slightly liquid. A sheet of the material, 4 inches thick, will freeze solid in 4 to 6 hours at -13°F . In fortification construction it is used for overhead cover, parapets, breastworks, or sandbag filler.

Section III. OBSTACLES

11-9. Classification

Obstacles are divided into two general classes depending on whether they are existing or are constructed for the express purpose of hindering movement.

a. Natural. A natural obstacle is any existing object or condition that is used to hinder movement including manmade objects not constructed as obstacles but used as such. Natural obstacles include swamps, rivers and streams, mountain ranges, climatic conditions, irrigation canals, and existing buildings or walls.

b. Artificial. An artificial obstacle is any manmade object constructed to hinder movement. Artificial obstacles include minefields, antitank ditches, contaminated areas, hedgehogs, road craters, demolished bridges, and barbed wire. It may be constructed entirely on land or partially under water as in the case of beach and river line obstacles.

c. Uses. Obstacles can be divided into three groups according to their uses. Seldom does an obstacle fall clearly into one of these three groups. More often than not an obstacle serves in two or all three capacities. This arbitrary classification of obstacles merely clarifies their primary uses.

(1) *Protective.* Protective obstacles are those obstacles used to provide security. Ob-

stacles of this type are usually artificial and include such items as wire, minefields, and various warning devices. They are intended primarily to prevent the enemy from making a surprise assault from areas close to a position.

(2) *Defensive.* Defensive obstacles are obstacles used to delay the enemy force in areas where it can be engaged with heavy, intense defensive fire. They may be either natural or artificial. A defended roadblock or an obstacle in front of a defensive position which stops or delays the enemy force once it is in range of defensive weapons are examples of this type. Defensive obstacles should be covered by appropriate fire, kept under observation, and should be employed in conjunction with protective obstacles.

(3) *Tactical.* Tactical obstacles are obstacles used to break up enemy attack formations and channelize the enemy force into areas where it is blocked by defensive obstacles or can be brought under intensive defensive fires. This tactical obstacle delays, harasses, or demoralizes the enemy by forcing it to employ dangerous or exhaustive breaching measures in areas not covered by fire.

11-10. Obstacle Construction Data

Tables 11-10 through 11-13 cover data used in construction of various artificial obstacles.

Table 11-10. Obstacle Construction Data

Obstacle	Construction method	Normal employment	Construction rate
Antitank ditch	By multiple-charge method— 10 ft deep	(1) For permanent system of fortifications: Construct across wide avenues of approach. (2) For hasty or temporary fortifications. Construct across only short distances—25 to 50 ft.	1 squad with power earth auger and demolition equipment can complete 100 yds in 12 hr.
	30 ft wide		
	By hand tools— 6 ft deep		
	12 ft wide		One platoon under average conditions can do 100 ft of triangular ditch in 7½ hr, and 100 ft of trapezoidal ditch in 14 hr.
	Using ¾-yd shovel with 2 operators and 3 to 10 finishers.		Platoon can dig 100 ft of triangular ditch in 4½ hr and 100 ft of trapezoidal ditch in 9 hr.
Log post obstacle	Substantial posts set in the ground, density of 1 post per linear foot, 2½- to 3½-ft projection.		1 squad with piledriver can complete 50 ft in 1 day under average conditions.
Contamination by persistent chemicals (when authorized).	Contaminate artificial obstacles to impede removal. Contaminate roads and areas as part of a barrier mission.	1 or more chemical mines per obstacle. 200 mines per mile of road, or—Airplane spray: Average area covered by 1 airplane— 80 yd long 300 yd wide	1 squad can contaminate 1 mile of road in 1½ hr.

Table 11-11. Wire and Tape Entanglement Materials

Material	Approx weight, kg	Approx length, m	No. carried by one man	Approximate weight of man-load kg
Barbed wire reel	41.5	400	½	21
Bobbin	3.5-4.0	30	2-4	7.3-14.5
Barbed tape dispenser	0.77	0.45	20	15.5
Barbed tape carrying case	14.5	300	1	14.5
Standard barbed tape concertina	14	15.2	1	14
Standard barbed-wire concertina	25.4	15.2	1	25
Expedient barbed-wire concertina	13.5	6.1	1	13.5
Screw pickets:				
Long	4	1.6	4	16.3
Medium	2.7	0.81	6	16.3
Short	1.8	0.53	8	14.5
U-shaped pickets:				
Extra long	7.25	2.4	3-4	21.8-29.0
Long	4.5	1.5	4	18.1
Medium	2.7	0.81	6	16.3
Short	1.8	0.61	8	14.5
Wooden pickets:				
Extra long	7.7-10.5	2.13	2	15.4-20.8
Long	5.4-7.25	1.5	3	16.3-21.7
Short	1.4-2.7	0.75	8	11.0-21.7

Table 11-12. Material and Labor Requirements for 300-Meter Sections of Various Barbed Wire Entanglements

Type of entanglement	Pickets				Barbed wire no. of 400 m, 41.5 kg reels ¹	No. of concertinas ⁴	Staples	Kgs of materials per lin m of entanglement ²	Man-hours to erect 300 m of entanglement ³
	Extra Long	Long	Medium	Short					
Double-apron, 4- and 2-pace	---	100	---	200	14-15(19) ⁵	---	---	4.6(3.5) ⁶	59
Double-apron, 6- and 3-pace	---	66	---	132	13-14(18) ⁵	---	---	3.6(2.6) ⁶	49
High wire (less guy wires)	---	198	---	---	17-19(24) ⁵	---	---	5.3(4.0) ⁶	79
Low wire, 4- and 2-pace	---	---	100	200	11(15) ⁵	---	---	3.6(2.8) ⁶	49
4-strand fence	---	100	---	2	5-6(7) ⁵	---	---	2.2(1.8) ⁶	20
Double expedient concertina	---	101	---	4	3	100	295	6.9	40
Triple expedient concertina	51	101	---	7	4	148	295	10.4	99
Triple standard concertina	---	160	---	4	3(4) ⁵	59	317	7.9(5.4) ⁶	30

¹ Lower number of reels applies when screw pickets are used; high number when U-shaped pickets are used. Add difference between the two to the higher number when wood pickets are used.

² Average weight when any issue metal pickets are used.

³ Man-hours are based on the use of screw pickets. With the exception of the triple-standard concertinas, add 20 percent to the man-hours when driven pickets are used. With experienced troops reduce man-hours by one-third. Increase man-hours by 50 percent for night work.

⁴ Based on concertinas being made up in rear areas and ready for issue. One expedient concertina opens to 6-meter length, as compared with 15 meters for a standard concertina; it requires 92 meters of standard barbed wire, also small quantities of No. 16 smooth wire for ties.

⁵ Number of 300 m, 14.5 kg barbed tape carrying case required if barbed tape is used in place of barbed wire.

⁶ Kgs of materials required per linear meter of entanglement if barbed tape is used in place of barbed wire and barbed tape concertina is used in place of standard barbed wire concertina.



CHAPTER 12

CAMOUFLAGE

Section I. ISSUE MATERIALS

12-1. General

Issue camouflage materials include cotton twine camouflage drape and flattop nets, wire netting, paint, wire, wire rope, cotton twine, fiber rope, wood and metal stakes and supports, decoys, and other miscellaneous items. Camouflage material is covered in detail in TM 5-200. FM 5-20 covers the principles of the use of such materials.

12-2. Nets and Net Sets

a. Nets are issued ungarnished or garnished in drape or flattop patterns and come in two color blends—all seasonal and desert.

(1) Drape nets and drape net sets are twine nets designed to provide concealment for vehicles, tanks, artillery, and other similar equipment from air or ground observation.

(2) Flattop nets are twine nets that are

stretched parallel with the ground to provide concealment from overhead and high oblique observation. The essential difference between flattops and drapes is the garnishing density and method of erection. The density of garnish on a flattop is much less than on a drape and the garnishing does not extend to the edges. Flattop nets are 65 percent and drape nets are 85 percent garnished.

(3) Detailed information on nets and net sets is provided in tables 12-1 through 12-3.

b. Camouflage drape net sets contain two or more nets for assembly, so garnished as to fit into the overall pattern of the set. See tables 12-4 and 12-5.

c. Wire netting (table 12-6), both garnished and ungarnished, is available in widths of 6 feet. Because of its bulk and stiffness, which allows it to hold its shape indefinitely, it is best suited

Table 12-1. Size, Weight and Cubage Data, Weight (lb) and Cubage (cu ft)

Net Size (ft)	Ungarnished		Garnished			
	Flattop and Drape		Flattop		Drape	
	Wt	Cu	Wt	Cu	Wt	Cu
15 x 15*	4.0	0.30	9	0.9	N/A	N/A
14 x 29	6.7	0.50	12	1.0	15.8	1.31
22 x 22	8.1	0.63	15	1.5	19.6	1.96
17 x 35	10.0	0.90	20	2.0	26.2	2.60
29 x 29	12.2	1.10	27	3.3	35.2	4.30
36 x 44	24.0	1.80	51	5.0	66.9	6.60
45 x 45**	34.0	2.50	N/A	N/A	78.5	7.90

*Flattop only.

**Drape only.

Table 12-2. Net Size Formulas

Drape	$W = 2H + W + 5'$ $L = 2H + L + 5'$
Flattop	$W = 4 (H + 2) + W$ $L = 4 (H + 2) + L$

W = width

L = length

H = maximum height of object being camouflaged

as covering material for molds or shaped screens. This type of netting is fire and rust resistant.

12-3. Supporting Materials

Supporting materials (table 12-7) are those required for attaching, suspending, or supporting camouflage materials, and include posts, stakes,

Table 12-3. Net Coverage Data for Selected Items of Equipment

	22x22	29x29	36x44	45x45		22x22	29x29	36x44	45x45
Armored vehicle launched bridge	---	---	---	2	Tank, combat, full tracked, 90 mm gun	---	---	---	2
Asphalt plant, 3-10 ton per hr	---	---	---	1	Tank, combat, full tracked, 105 mm gun	---	---	---	2
Euger, earth, skd mtd	---	---	---	1	Tractor, full tracked, high speed	---	---	---	2
Carrier, light weapons; infantry ½-ton, 4x4	1	---	---	---	Tractor, full tracked, low spd, dsl drv, medium	---	---	---	1
Carrier, personnel, full tracked: armored	---	---	---	1	Tractor, wheeled, dsl drv, industrial	---	---	---	1
Combat engineer vehicle	---	---	---	1	Tractor, Universal Engineer	---	---	---	1
Crane shovel, basic unit, crawler mtd	---	---	---	2	Trailer, 2-ton, 2 wheel	---	---	---	1
Crane shovel, basic unit, trk mtd	---	---	---	2	Trailer, amphibious; cargo ¼-ton, 2 wheel	1	---	---	---
Crusher, air trans, jaw type, wheel mtd, 15 tons per hr	---	---	---	1	Trailer, cable reel; 3½-ton	---	1	---	---
Firefighting equipment set, trk mtd, AACFT crash	---	---	---	2	Trailer, cargo: ¾-ton, 2 wheel	---	---	---	1
Grader, road, mtd, dsl drv, hvy, 6x4, front wheel steer	---	---	---	1	Trailer, cargo: 1½-ton, 2 wheel	---	---	---	1
Gun AAA Sp: Twin 40 mm*	---	---	---	---	Trailer, flatbed: 10-ton	---	2	---	---
Howitzer, hvy, self-propelled; full tracked, 8-inch	---	---	---	2	Trailer, laundry unit, mobile	---	2	---	---
Howitzer, 155 mm, towed*	---	---	---	---	Trailer, rclm and maint	---	---	---	1
Howitzer, 105 mm towed*	---	---	---	---	Truck, ambulance, ¼-ton, 4x4	---	---	---	1
Howitzer, medium, self-propelled; full tracked, 155 mm	---	---	---	2	Truck, ambulance, ¾-ton, 4x4	---	---	---	1
Howitzer, self-propelled, 105 mm, full tracked	---	---	---	2	Truck, bridge, 5-ton	---	---	---	1
Howitzer, self-propelled, 175 mm, full tracked	---	---	---	2	Truck, cargo, ¾-ton, 4x4	---	2	---	---
Launcher, multiple rkt, 4.5-inch	---	---	---	1	Truck, cargo, 2½-ton, 6x6	---	---	---	2
Launcher, rocket: 762 mm, truck mtd*	---	---	---	---	Truck, cargo: 5-ton, 6x6	---	---	---	2
Loader, scoop type, dsl drv 4, wheel	---	---	---	1	Truck, cargo, dump, 2½-ton, 6x6	---	---	---	1
Mixer, concrete, trl mtd, gas drv	---	---	---	1	Truck, dump: 5-ton, 6x6	---	---	---	2
Mobile assault float bridge (1 transporter w/load)	---	---	---	2	Truck, tank: gasoline, 2½-ton, 6x6, 1200 gal	---	---	---	1
Mortar, infantry, self-propelled, full tracked, 4.2-inch	---	---	---	1	Truck, tank: water, 2½-ton, 6x6, 1000 gal	---	---	---	1
Paving machine, bituminous, crawler mtd	---	---	---	1	Truck, tractor: 2½-ton, 6x6	---	---	---	1
Recovery vehicle, full tracked: med	---	---	---	2	Truck, tractor: 5-ton, 6x6	---	---	---	1
Roller, road, towed, pneumatic tires, 4 tires, 85,000 lb cap	---	---	---	2	Truck, tractor: 10-ton, 6x6	---	---	---	2
Scraper, road, towed, cable op 12 cu yd	---	---	---	2	Truck, wrecker: 5-ton, 6x6	---	2	---	---
Scraper, road, towed, 18 cu yd	---	---	---	2	Truck, utility, ¼-ton, 4x4	---	1	---	---
Semitrailer, petrol, lub, mbl	---	---	---	2	Truck, van, expansible, 2½-ton, 6x6	---	---	---	1
Semitrailer, van: cargo, 6-ton	---	---	---	2	Truck, van: shop, 2½-ton, 6x6	---	---	---	2
Semitrailer, van: cargo, 12-ton 4 wheel	---	---	---	2	Truck, wrecker: crane, 2½-ton, 6x6	---	---	---	1
Semitrailer, van: electronic, 2 wheel, 3-ton and 6-ton	---	---	---	2	Truck, wrecker: light, 2½-ton, 6x6	---	---	---	1
Semitrailer, van: medical, 3-ton, 2 wheel	---	---	---	2	Water purification equip set, trk mtd	---	---	---	1
Semitrailer, van: refrigerator, 7 ½-ton, 2 wheel	---	---	---	2					
Semitrailer, van: supply, 12-ton	---	---	---	2					
Shop equipment contact maint, trk mtd	---	---	---	1					

*Use net set, field artillery, drape, 90x90

wire, wire rope, cable, rope, twine, and steel clips and brackets. They can be obtained through normal supply channels, or from commercial sources, or improvised from field expedient materials.

12-4. Garnishing, Texturing, and Coloring Materials

a. Garnishing materials (table 12-8) are applied to such items as nets and screens to add the desired texture. Many such materials are available through supply channels and there is

Table 12-4. Characteristics of Drape Net Sets

Net set, drape	Size and No. of nets	Total (sq ft)	Weight (lb)	Cubage (ft)	Packaging	Representative item of equipment
72' x 88'	36' x 44' (4)	6,336	1,070	60.5	5 bags 3 pole-carrying boxes	155 mm howitzer, towed
58' x 58'	29' x 29' (4)	3,364	684	34	3 bags 2 pole-carrying boxes	105 mm howitzer, towed
44' x 44'	22' x 22' (4)	1,936	365.5	21.5	3 bags 1 pole-carrying box	Gun, self-propelled, 40 mm
34' x 35'	17' x 35' (2)	1,190	306	15	2 bags 1 pole-carrying box	The items these sets were designed to conceal are no longer standard. The nets remain in the system and can be adapted to other weapons.
28' x 29'	14' x 29' (2)	812	145	6	1 bag (nets) Ribs (loose)	
90' x 90' (Basic set)	45' x 45' (4)	8,100	1,320	79	5 bags 2 pole-carrying boxes 3 heavy-duty pole-carrying cases	All heavy field artillery

Table 12-5. Standard Camouflage Nets and Drapes

(All are flame-resistant and treated to reduce detection by infrared and Camouflage Detection photography)

A. Flat-Top Nets (cotton twine, garnished)

Nomenclature	Garnishing	Fed Stock No.
15 ft x 15 ft	All-Seasonal	1080-725-5114
15 ft x 15 ft	Desert	1080-807-8254
14 ft x 29 ft	All-Seasonal	1080-804-3438
14 ft x 29 ft	Desert	1080-804-3439
22 ft x 22 ft	All-Seasonal	1080-804-3443
22 ft x 22 ft	Desert	1080-804-3444
17 ft x 35 ft	All-Seasonal	1080-804-3441
17 ft x 35 ft	Desert	1080-804-3442
29 ft x 29 ft	All-Seasonal	1080-804-3445
29 ft x 29 ft	Desert	1080-804-3446
36 ft x 44 ft	All-Seasonal	1080-807-3716
36 ft x 44 ft	Desert	1080-804-3448

B. Drape Nets (cotton twine, garnished)

Nomenclature	Garnishing	Fed Stock No.
22 ft x 22 ft	All-Seasonal	1080-804-3336
22 ft x 22 ft	Desert	1080-804-3337
29 ft x 29 ft	All-Seasonal	1080-804-3338
29 ft x 29 ft	Desert	1080-804-3339
36 ft x 44 ft	All-Seasonal	1080-722-7264
36 ft x 44 ft	Desert	1080-804-3435
45 ft x 45 ft	All-Seasonal	1080-722-7263
45 ft x 45 ft	Desert	1080-804-3437

C. Drape Net Sets

Nomenclature	Garnishing	Fed Stock No.	Supply Catalog
Camouflage Net Set, Fld Arty: Drape: 72 ft wide 88 ft long (former Drape Net Set No. 1).	All-Seasonal	1080-375-8983	SC 1080-97-CL-E05
	Desert	1080-752-8916	
Camouflage Net Set, Fld Arty: Drape: 58 ft wide, 58 ft long (former Drape Net Set No. 2).	All-Seasonal	1080-279-0673	SC 1080-97-CL-E06
	Desert	1080-752-8917	

<i>Nomenclature</i>	<i>Garnishing</i>	<i>Fed Stock No.</i>	<i>Supply Catalog</i>
Camouflage Net Set, AAA Gun: Drape: 44 ft wide, 44 ft long (former Drape Net Set No. 3).	All-Seasonal	1080-279-0675	SC 1080-97-CL-E07
	Desert	1080-752-8918	
Camouflage Net Set, AA Mach Gun: Drape: 34 ft wide, 35 ft long (former Drape Net Set No. 4).	All-Seasonal	1080-279-0674	SC 1080-97-CL-E08
	Desert	1080-752-8919	
Camouflage Net Set, Fld Arty: Drape: 90 ft wide, 90 ft long (former Drape Net Sets No's 5 & 6).	All-Seasonal	1080-542-0376	SC 1080-97-CL-E16
	Desert	1080-752-8930	
Camouflage Net Set, Guided Missile Arty Launch Site: Drape: 90 ft wide, 180 ft long (former Drape Net Set No. 7).	All-Seasonal	1080-542-0378	SC 1080-97-CL-E15
	Desert	1080-752-8928	
Camouflage Net Set, AA MC Semi-Rigid: 28 ft wide, 29 ft long.	All-Seasonal	1080-375-8991	SC 1080-97-CL-E03
	Desert	1080-752-8915	

Table 12-6. Steel Wire Netting

Type*	Size	Weight (lb)	Cubage (cu ft)	Remarks
Galvanized, garnished with fabric.	6' x 150' rolls	95	5.5	Fabric garnished netting is less expensive than other garnished nets but it lacks the durability of the others and is intended for use only where short term requirements exist (a few months). Although this is bonderized to prevent rusting, in humid climates both the steel wool and the wire will rust.
Welded, garnished with steel wool.	6' x 75' rolls	100	6.4	

*All types come in standard camouflage colors.

Table 12-7. Wire and Tape

Material	How issued	Average tensile strength	Recommended uses
16-gage steel wire -----	12 lb coil of 1,150 feet	250 lb	To join edges of nets.
	125 lb coil of 12,200 feet		Fasten nets to frames. Wire in paths. Fasten garnishing to camouflage structures. Other general purposes requiring a light pliable wire.
10-gage steel wire -----	12 lb coil of 240 feet	1,050 lb	Normal camouflage construction.
Marline, jute tarred -----	2-ply, 10 pound coil	110 lb (new)	Mark paths-general utility.
Cotton tape -----	¾" 500 foot roll	n/a	Mark access paths.

an unlimited number of materials that can be improvised.

b. Texturing materials (table 12-9) are used to eliminate shine from smooth surfaces. They may be spread loosely or affixed (table 12-10),

depending upon the use of the item they are attempting to conceal.

c. Paints are the most common item used for altering the color of surfaces (tables 12-11 through 12-13). Standard camouflage paint is

Table 12-8. Garnishing Requirements

Net size (feet)	Number of garnishing strips 2" x 60"		Approximate man-hours	
	Flattop	Drape	Flattop	Drape
15 x 15	234	306	5	8
14 x 29	422	550	14	20
22 x 22	454	594	15	19
17 x 35	617	808	19	26
29 x 29	874	1,142	30	40
36 x 44	1,645	2,160	55	60
45 x 45	2,110	2,760	60	63

Note. Color percentages

All-seasonal: 60% dark green
40% earth brown

Desert: 80% sand
10% olive drab
10% light green

For example: A 15' x 15' drape net garnished in an all-seasonal blend requires 188.6 (184) strips of dark green and 122.4 (122) strips of earth brown.

available through supply channels in 10 colors, in addition to black and white. This paint is specially prepared and designed for camouflage uses and is the best type to use when it is available.

12-5. Decoy Items

Pneumatic decoy targets (table 12-14) are prefabricated, three dimensional, pneumatic simulation devices. They are intended to be displayed with partial camouflage, so as to simulate military vehicles, tanks, guns, and other standard equipment to unaided visual observation at 1500 feet and beyond.

Table 12-9. Suggested Garnishing and Texturing Materials

Material	Coverage per ton* (sq yd)	Suggested sources	Remarks
Rock chips, ½-inch -----	90	Quarries and road building contractors.	Good texture and very durable. Used on traffic bearing surfaces.
Gravel -----	90	Gravel pits -----	Same as for rock chips.
Open graded aggregate, 1¼-inch.	22	Same as for rock chips -----	Same as for rock chips.
Tin cans -----	900	Salvage depots, mess halls -----	Good texture. Used on nets and non-traffic bearing surfaces.
Slag -----	90	Iron and steel blast furnaces -----	Fair texture. Almost as durable on traffic bearing surfaces as rock chips and gravel.
Cinders -----	90	RR roundhouses, boilers, factories.	Same as for slag.
Wood chips, 1-inch -----	800	Paper mills, wood pulp concerns..	Very good texture. Not as durable on traffic bearing surfaces as rock chips and gravel.
Sawdust -----	3,000	Lumber mills, furniture manufacturers, plywood mills.	Fairly durable under wear and abrasion, but very poor texture. Not highly recommended.
Leather chips -----	115	Shoe and leather goods manufacturers.	Good texture and fair durability under wear.
Coffee beans -----	90	Coffee concerns -----	Same as leather chips.
Wood cubes, 1-inch -----	160	Lumber, made on site -----	Fair texture, not too durable under wear, and abrasion.
Cotton seed hulls -----	3,000	Cotton growing and processing concerns.	Good texture. Wears rapidly under traffic.
Fabric strips -----	2,000	Issued; textile concerns -----	Issued strips come in osnaburg or burlap in camouflage colors. Recommended use for garnishing only.
Excelsior -----	2,000	Wood pulp concerns -----	Very good texture. Will not stand up under wear and abrasion.
Pine bow tips -----	400	Local labor -----	Fair texture. No wearing resistance.
Pine cones -----	160	Local labor -----	Good texture. No wearing resistance.
Coir (shredded coconut shell fiber).	2,000	Coconut growing and processing concerns.	Same as pine cones.
Feathers -----	20,000	Poultry farms and slaughter houses, pillow manufacturers.	Excellent texture. No wearing resistance.
Leaves and chopped palm fronds.	2,000	Local labor -----	Fair texture. No durability under wear.
Spanish Moss -----	2,000	Local labor -----	Excellent texture. No resistance to wear.
Seaweed -----	2,000	Local labor -----	Fair texture. No resistance to wear.
Glass fiber -----	N/A	Issued -----	Excellent texture. Issued between 2 layers of chicken wire in rolls 100' x 6'. In all camouflage colors except white and black, used for semipermanent camouflage construction.

Table 12-9. Suggested Garnishing and Texturing Materials—Continued

Material	Coverage per ton* sq yd	Suggested sources	Remarks
Steel wool -----	N/A	Issued -----	Excellent texture. Issued attached to rolls of welded rectangular meshed screen. It is fire-proof and rust resistant. Good texture; no durability.
Shredded paper -----	2,000	Paper mills, junk dealers -----	

*These figures are approximate for purpose of comparison and rough estimates.

Table 12-10. Adhesive Table

(Located in back of manual)

Table 12-13. Tonedown Materials for use on Concrete

(Located in back of manual)

Table 12-11. Coating and Staining Materials

(Located in back of manual)

A paratrooper decoy is available through supply channels but employment doctrine is classified. Table 12-14 lists other decoys that are available.

Table 12-12. Coverage Data

(Located in back of manual)

Table 12-14. Decoy Target Logistical Data

Nomenclature	Stock No.	Erection time (man-minutes)	Deflation time	Crated weight (pounds)	Uncrated weight (pounds)	Crated bulk (cubic ft)	Uncrated bulk
Decoy target, gun antiaircraft; self-propelled, 40-mm -----	1080-571-6463	15	14	625	429	51.2	43.5
Decoy target, gun; field artillery, towed, 155-mm -----	1080-570-6517	8	4	406	271	35.7	30
Decoy target, howitzer; medium, towed, 105-mm -----	1080-570-6519	3	5	147	93	14.7	12
Decoy target, howitzer; light, towed, 155-mm -----	1080-570-6520	6	5	240	150	25.5	20
Decoy target, howitzer; self-propelled, 105-mm -----	1080-571-6462	19	23	743	482	65	58
Decoy target, tank; combat, full-tracked, medium, 76-mm gun, M41 -----	1080-536-4587	18	18	812	450	94	80.5
Decoy target, tractor; full-tracked, high-speed, M5 -----	1080-570-6530	13	15	447	300	39.5	32.5
Decoy target, tractor; full-tracked, high-speed, M8A1 -----	1080-570-6532	20	18	698	466	59.5	51.5
Decoy target, truck; cargo, 2½-ton, 6 x 6, M34 -----	1080-570-6524	16	18	567	351	56	48
Decoy target, truck; wrecker, medium, 5-ton, 6 x 6, M62 w/winch, W/E -----	1080-570-6525	28	25	767	470	77	66

Section II. FIELD EXPEDIENTS

12-6. General

The use of field expedients in camouflage practices is limited only by one's ingenuity and imagination. Field expedients can be of either manmade or natural materials.

12-7. Natural Materials

a. In all camouflage planning, natural materials are used whenever possible because of their

availability, their adaptability, and their excellent camouflage properties. They are the most economical camouflage materials and because of their availability they reduce logistical requirements.

b. There are four types of natural camouflage material (table 12-15): growing vegetation (table 12-16), cut vegetation, inert substances of the earth, and debris (both natural and man-made, usually having no apparent organization).

Table 12-15. Common Natural Camouflage Materials

Growing vegetation	Cut and dead vegetation	Inert material	Debris
Legumes	Dried grasses	Earth	Tin cans
Low growing plants	Hay	Sand	Wreckage
Grasses	Straw	Gravel	Rubble
Vine and creepers	Branches	Clay	Rubbage
Shrubs and trees		Mud	

Table 12-16: Vine Suitable for Camouflage in Temperate Climate

Common and botanical names	Uses and camouflaging qualities	Culture	Propagation	Height of growth
Actinidia. ¹ <i>Actinidia</i>	Covering flat-tops, wire fences; dense growth.	Prefers coolness, moisture, sun, or partial shade.	Seeding or layering ..	20 to 30 feet.
Dutchman's Pipe. ¹ <i>Aristolochia</i> .	Covers and hides or screens. Large foliage.	Grown in any soil with little care. Sun or shade.	Layering; cuttings ...	30 feet or more, 4 to 6 feet annually.
Cinnamon Vine. Yam, or Chinese Potato. ² <i>Dioscorea batatas</i> .	Spreads rapidly over any support; dense foliage.	Easy: no care except to provide support.	Tubers or seeds	10 to 30 feet.
Moonflower. ³ <i>Calonyction aculeatum</i> .	Ideal where temporary screen or covering required rapidly.	Plenty of water and sunshine.	Seeding (must be done carefully).	30 to 40 feet in a single season.
Hop. ³ <i>Humulus</i> .	Dense growth of foliage; must have elastic support or will pull itself out of ground.	Thrives in heat or drought; requires good soil, some care.	Seed in fall or early spring; takes 8 to 10 days to germinate.	20 feet in 3 or 4 weeks.
Honeysuckle. ^{3,4} <i>Lonicera</i>	Dense growth where desired, cover steep banks.	Any soil	Layering: cuttings ...	From ground cover to 30 feet tall; 18 to 20 feet annually after becoming well established.
Fleeceflower. <i>Polygonum</i> .	Cover walls of buildings, framework; must be trained on wires.	Any soil	Plants may be divided; root branches in soil; sow seeds as soon as ripe.	Attains 25 feet in short time.
Kudzu Vine. <i>Pueraria</i> .	Wherever quick screen is desired.	Prefers heavy soil: withstands drought.	Division of tuberous roots; layering if soil is kept moist.	Often attains 50 feet in a single season after becoming well-established.
Bittersweet. ⁴ <i>Celastrus</i>	Cover walls, banks, rocky ground; tied to a stake, it may be grown to form a tree.	Very little care; almost any soil.	Cuttings of mature soft wood; layering; seeding.	3 to 10 feet.

¹ Does not die to ground.² Tuberous roots.³ Grown from seed each year; these will die after the freezing weather of late fall.⁴ Evergreen; the leaves are not shed in winter.

Note. Vines provide very good camouflage, but require extensive time periods for growth.

c. Preservation of cut vegetation presents a major problem since many forms of vegetation do not survive long without water (table 12-17). This can be alleviated by supplying water

or by treating the vegetation with calcium chloride and painting with oleoresinous paint or by treating with ammonium thiocyanate and sorbitol.

Table 12-17. Lasting Qualities of Cut Foliage

PLANT	HOURS in sunlight w/o water	DAYS (24/hr) in sunlight w/water
Alder	3-4	1-2
Apple	8+	6+
Ash	0-2	1-
Aspen (Poplar)	0-2	1-
Australian Pine***	24-72	8-16
Basswood (Linden)	5-7	3-5
Beech	5-7	3-5
Birch	3-4	1-2
Black Locust	0-2	1-
Blueberry*	8+	6+
Butternut*	0-2	1-
Cherry	3-4	1-2
Chestnut	5-7	3-5
Coconut Palm Leaves***	72-144	4-8
Elderberry	0-2	1-
Elm	3-4	1-
Fishtail Palm Leaves***	72-144	4-8
Hawthorne	8+	6+
Hickory*	3-4	1-2
Lilac	5-7	6+
Mangrove***	12-24	½-1
Maple	8+	1-2
Palomaria***	72-144	8-16
Privet**	8+	6+
Screw Pine***	72-144	3-6
Sumac*	0-2	3-5
Sycamore (Plane)	3-4	1-2
Walnut	0-2	1-
White Oak Group	5-7	3-5
Willow	0-2	1-
Yellow Poplar (Tulip Tree)	3-4	1-2

*North American only.

**European only.

***Tropical only.

Table 12-18. Raw Molasses (for Field-Expedient Paint)

Type	Field expedient.
Colors available	Brown.
Source	Commercial sugar refineries; practicable only in areas where crude molasses is plentiful.
Recommended uses	Lay dust. Tone earth, as on run- way. In extreme emergency, as an adhesive.
Durability	Unstable, not waterproof.
How prepared	Use as supplied. Thin with water; the more water, the less adhesion.
How applied	Asphalt distributor. Brushed with broom. Mobile spray equipment. May be covered with thin coating of local earth.
Drying time	Never dries; always sticky.
Coverage	5 to 20 square feet per gallon.

12-8. Manmade Material

a. In addition to issued camouflage materials there are many manmade materials that can be used as field expedients (tables 12-18 through 12-20). Again, this is limited only by one's ingenuity and inventiveness.

b. Adhesives, dyes, and paints can be made by using molasses, crankcase oil, charcoal, vegetation, and waste materials from mines, factories, and messhalls.

c. Smoke, snow fencing, truck tarpaulins, tin

Table 12-19. Used Crankcase Oil (for Field-Expedient Paint)

Type issued	Salvage.
Colors available	Brownish.
Source	Motor pools, air bases.
Recommended uses	To tone down concrete. To lay dust. To tone down stabilized soil. To tone down soil around en- trenchments.
Durability	Fair.
How prepared	Ready for application. May be mixed with native colored earths by hand or in motor- driven mixer.
How applied	Spraying, asphalt distributor.
Climatic limitations	May be applied under any weather conditions.
Coverage	20 square feet per gallon.

Table 12-20. Field-Expedient Tentage Stain

Type issued	Field expedient.
Colors available	Dark gray.
Source	Manufacture by troops.
Recommended use	Tentage.
Durability	Fair.
How prepared	BILL OF MATERIALS: Local earth. Soot. G.I. or field ex- pedient soap. Paraffin. Water.
How applied	PROCEDURE: Mix local earth with soap solution in proportion of ½ pound of soap to 8 gallons of water in which soot soaked in a little paraffin has been added. Enough soot is used to form a liquid possessing the desired tone of gray.
Drying time	Brushing. Swabbing with a rag. Variable, but fairly rapid.
Resultant surface	Flat, lusterless.
How removed	Not practicable.
Climatic limitations	Not recommended for freezing temperatures.

cans, and feathers are a few materials that can be used as expedient camouflage materials.

d. Decoys can be constructed from lumber and

other structural material, cloth, canvas, paints, wrecked vehicles and equipment, stacked supplies, and plaster or lime.



Apr 1971

CHAPTER 13

UTILITIES

Section I. WATER SUPPLY AND DISTRIBUTION

13-1. References

TM 5-297, TM 5-700, and FM 101-10-1 cover in detail the requirements, supply, and distribution of water to troops in the field.

13-2. Responsibilities

a. The engineer and chemical research and development agencies under the Army Materiel Command (AMC) are responsible for developing, storing, and providing equipment for water purification and kits for testing water to the units in the field performing water purification.

b. Providing potable water is an engineer service under the staff supervision of the logistics officer. The logistics officer advised by the engineer, will determine the potable water requirement. The engineer finds, records, and develops water sources to meet the requirement; treats water and dispenses it; coordinates inspection and testing procedures with the surgeon; and maintains (organizational and limited direct support maintenance) water processing and purification equipment. Rail and overwater bulk transportation of water is provided by the transportation service. The transportation service also establishes and operates water points to produce the water needed for boilers in rail and marine operations. Laundry and bath units and chemical decontamination units operate water points to meet their operational requirements. Decontamination units need assistance from the engineer when their operational water requirement exceeds their capability. The surgeon inspects and approves water sources, defines degree of treatment required, and approves treated water.

c. In addition all unit commanders have the responsibility to provide units and individuals of their command with the required amount of safe drinking water at all times. They must take measures to insure an understanding of the perils of drinking unsafe water by all personnel

of the command, and enforce strict discipline so the men will—

- (1) Drink approved water only.
- (2) Not waste purified water.
- (3) Protect water sources by good sanitary habits.

d. The Army Medical Service is responsible for inspecting water points and facilities, conducting bacteriological and special chemical tests and rendering advice on treatment (chlorine resistant organisms, industrial waste, and unusual contaminants) of water sources.

e. The logistics staff is responsible for the allotment of resources, distribution schedules, control at water points, storage of reserves, and procurement of additional resources (vehicles, containers, and labor). They must also take into account the planned consumption on a long range basis.

13-3. Water Sources

When the sources of water in an area are free from unusual impurities, such as toxic metals and chemicals from industrial wastes, the following principles guide the selection of the source.

a. In populated areas, use established public systems to the fullest extent.

b. Use existing springs or wells next. The quality of water from these sources is usually better than from surface sources.

c. If public or ground-water sources are not readily available, use surface-water sources such as rivers, streams, lakes, or ponds, including flowing subsurface water in dry streambeds.

d. When other sources are not available, develop ground-water sources. Development of new ground-water sources is not practicable for an army on the move. In rear areas, a ground-water

source is usually best, especially where surface-water sources are highly contaminated.

e. When no fresh-water source can be found, and sea water is available, use distillation units to purify the sea water.

f. In Arctic areas melt snow or ice to obtain water.

g. In general, every water source used by troops must be initially and periodically checked for contamination.

13-4. Water Consumption

Table 13-1 shows approximate figures for per-capita water demand by troops in a theater under various conditions. The figures are subject to considerable variation because of climate, terrain, physical condition of troops, water discipline, and other factors.

13-5. Measurement Flow

a. Stream Flow. $Q = av$, where Q is quantity of water in cubic feet per second, a is area of cross section of stream in square feet, and v is average velocity of stream in feet per second. Determine a by estimate or measurement. Esti-

mate v by measuring the velocity of a chip floating in midstream and multiplying this by 0.85.

b. Springs. Note the time required to fill a container of known capacity. This method is probably more accurate and practicable for field use than methods described in *e* and *f* below unless flow is too great to handle in this manner.

c. Free-Flowing Artesian Wells. If the well discharges through a vertical pipe, measure the height of the jet and apply this measurement to figure 13-1.

d. Wells. Pump the well at a rate nearly equal to the rate of flow into the well. Measure the amount obtained by flowing into a suitable vessel or compute the rate of flow by the use of figure 13-2 or 13-3.

e. Rate of Flow in Full-Flowing Horizontal Pipe. To determine the rate of flow (in gallons per minute) from full-flowing horizontal pipes, use the formula illustrated in figure 13-2.

f. Discharge From Partially Filled Horizontal Pipe. To determine the rate of flow (in gallons per minute) from partially filled pipes divide the height of the fluid in the pipe (K , in inches) by the diameter (D , in inches). If K/D is be-

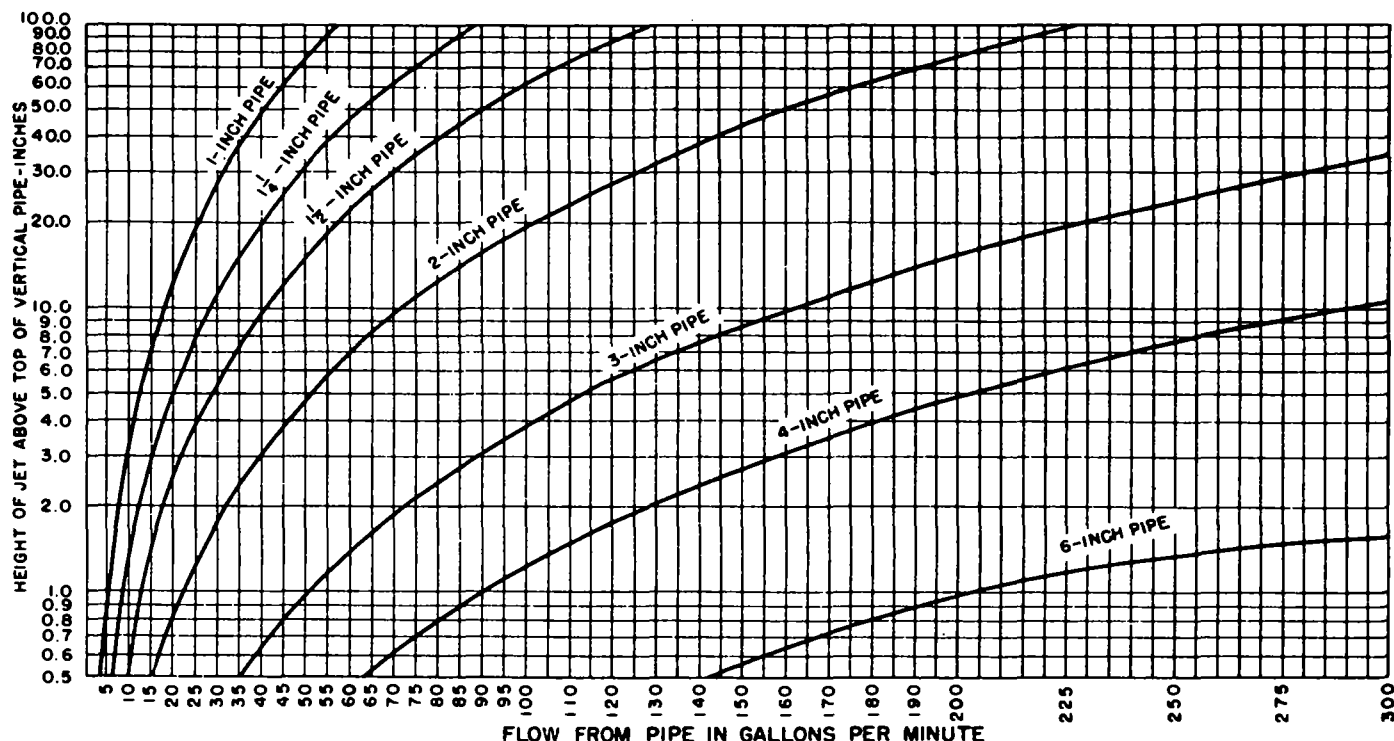
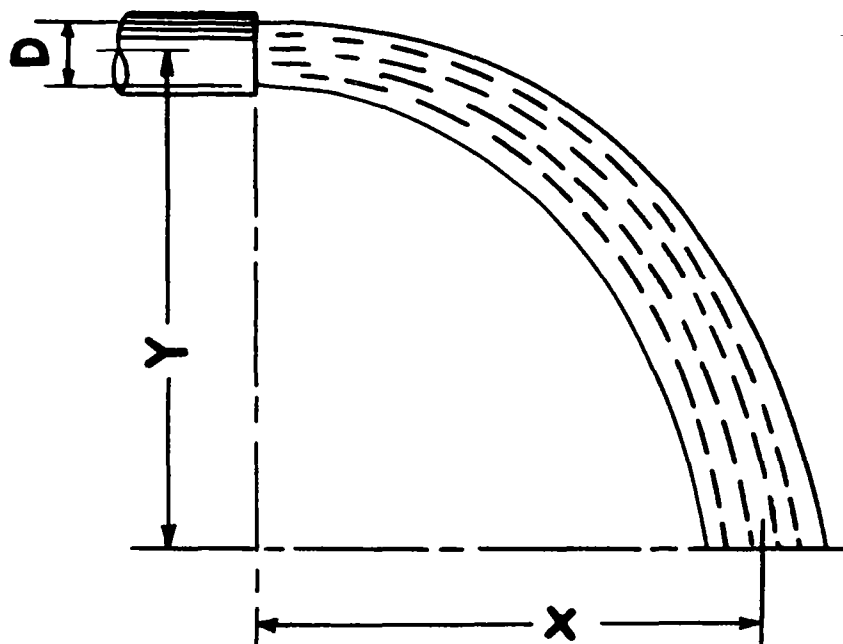


Figure 13-1. Flow from artesian well-vertical well pipe.

Table 13-1. Daily Water Requirements

1 Unit consumer	2 Conditions of use	3 Gal per unit consumer per day		4 Remarks
		Temperate/cold climate	Desert/jungle	
Man -----	In combat:			
	Minimum -----	$\frac{1}{2}$ -1	¹ 2-3	For eating and drinking only, periods not to exceed 3 days.
		2	¹ 3-4	When field rations are use.
	Normal -----	3	² 6	Drinking plus small amount for cooking or personal hygiene.
	March or bivouac ---	2	² 5	Minimum for all purposes.
	Temporary camp ---	5	-----	Desirable for all purposes (does not include bathing).
	Temporary camp with bathing facilities ..	15	-----	Includes allowance for waterborne sewage system.
	Semipermanent camp	30-60		
	Permanent camp --	60-100		
Vehicle -----	Level and rolling country	1/8-1/2	-----	Depending on size of vehicle.
	Mountainous country.	$\frac{1}{4}$ -1	-----	Depending on size of vehicle.
Locomotive (steam) -----	Standard military -----	Variable	-----	150 gallons per train-mile.
	Commercial -----	Variable	-----	200 gallons per train-mile.
Hospital -----	Drinking and cooking ---	10 per bed	-----	Minimum; does not include bathing or water for flushing.
	Water waterborne sewage.	50 per bed	-----	Includes water for medical personnel.
Impregnating plant, clothing, M2A1.	Maximum impregnating capacity.	2,400	-----	Aqueous process. Includes 2,000 gallons for plant operations and 400 gallons for washing and cleaning purposes.
QM Bakery company (mobile).	Two 10-hour shifts ----	2,600	-----	Water for making bread and cleaning baking utensils.
QM laundry company -----	Two 10-hour shifts ----	64,000 (4,000 per unit.)		
QM clothing exchange and bath company.	Two 10-hour shifts ----	360,000 (60,000 per unit.)		
Truck-mounted 400-gallon decontaminating apparatus.	Decontamination -----	4,000	-----	Water obtained from natural source when available.
Chemical base laboratory, M2.	Normal laboratory work.	300		

¹ For unacclimatized personnel or for all personnel when dry bulb readings exceed 105° F in the jungle.² Maximum consumption factor is dependent upon work performed, solar radiation, and other environmental stresses.



NOTE. Jet must be full flowing; no contraction or enlargement.

$$\text{Flow in gpm} = \frac{2.83 \cdot D^2 \cdot X}{\sqrt{Y}}$$

D = Inside diameter of pipe
X = Horizontal distance in inches
Y = Vertical distance in inches

Example using formula:

Given: A 3-inch-diameter standard pipe (D = 3.07") held 16 inches from ground (Y = 16"). X determined by measurement (X = 28").

$$\frac{2.83 \cdot 3.07^2 \cdot 28}{\sqrt{16}} = \frac{2.83 \cdot 9.4 \cdot 28}{4} = 187 \text{ gpm}$$

Figure 13-2. Flow from full-flowing horizontal pipe.

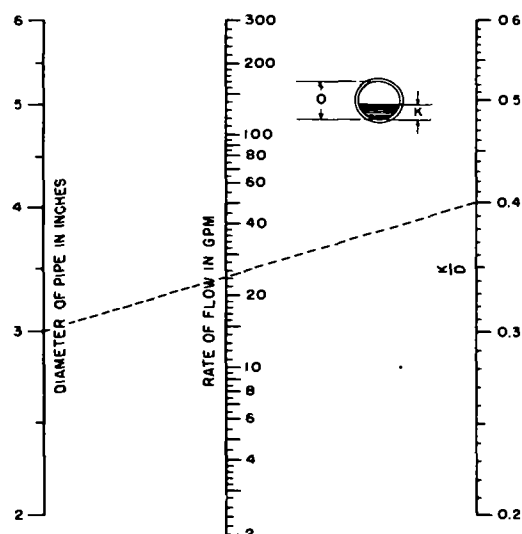


Figure 13-3. Flow from partially filled horizontal pipe; good for K/D values between 0.2 and 0.6.

tween 0.2 and 0.6, apply the value to the alignment chart (fig 13-3).

13-6. Pump and Flow Tables

Tables 13-2 through 13-8 provide information on flow of water through hose, pipe and nozzles; effect of altitude on pump lift; and equivalency and conversion factors.

13-7. Head-Pressure Conversion Factors

The head of water in feet and the resultant static pressure in psi (pounds per square inch) are related as follows:

$$\text{Pressure} = \text{head} \times 0.4331$$

$$\text{Head} = \text{pressure} \times 2.31$$

13-8. Loss of Head in 1½-Inch Hose

For various flows in gallons per minute, the loss of head per hundred feet of 1½-inch hose is given in figure 13-4.

Table 13-2. Flow of Water (Gallons per Minute) Through Small-Bore Hose ¹

Hose (internal diameter inches)	Water pressure, pounds per square inch									
	20	30	40	50	60	70	80	90	100	125
1.00	23	28	33	37	40	43	46	49	52	58
1.25	40	50	57	64	70	76	81	86	90	101
1.50	64	78	90	101	111	120	128	135	143	159
2.00	130	159	184	206	227	242	262	275	292	326
2.50	226	278	322	358	394	425	455	482	509	566
3.00	356	437	504	570	620	665	715	755	800	890
4.00	745	910	1,055	1,180	1,292	1,395	1,492	1,582	1,670	1,850

¹ Data shown are based on 100-foot length of hose, laid in a straight line with open discharge end. For each set of couplings, deduct 5 percent.

Table 13-3. Maximum Quantities of Water in Gallons Per Minute Which Can Be Pumped Through 100 Feet of Wrought-Iron Pipe at Various Pressures

Pressure	Pipe diameter (inches)								
	½	¾	1	1¼	1½	2	2½	3	4
17 psi -----	3.2	9.1	18.7	33.5	51.6	106	200	290	589
30 psi -----	5.0	14.0	28.0	52.0	78.0	160	308	436	885
40 psi -----	6.0	16.0	33.0	60.0	90.0	184	350	504	1,023
50 psi -----	6.5	17.5	37.0	70.0	101.0	206	390	564	1,143
60 psi -----	7.0	19.5	40.0	76.0	110.0	226	430	617	1,252
75 psi -----	7.5	22.0	45.0	85.0	123.0	253	480	690	1,400
100 psi -----	9.0	25.0	52.0	99.0	142.0	292	558	797	1,607

Table 13-4. Theoretical Discharge of Nozzles in United States (Gallons Per Minute)¹

Head		Velocity of discharge (feet per second)	Diameter of nozzle in inches									
Psi	Feet		1/16	1/8	3/16	1/4	5/8	1/2	5/8	3/4	7/8	1
10	23.1	38.6	0.37	1.48	3.32	5.91	13.3	23.6	36.9	53.1	72.4	94.5
15	34.6	47.25	.45	1.81	4.06	7.24	16.3	28.9	45.2	65.0	88.5	116.0
20	46.2	54.55	.52	2.09	4.69	8.35	18.8	33.4	52.2	75.1	102.0	134.0
25	57.7	61.0	.58	2.34	5.25	9.34	21.0	37.3	58.3	84.0	114.0	149.0
30	69.3	66.85	.64	2.56	5.75	10.2	23.0	40.9	63.9	92.0	125.0	164.0
35	80.8	72.2	.69	2.77	6.21	11.1	24.8	44.2	69.0	99.5	135.0	177.0
40	92.4	77.2	.74	2.96	6.64	11.8	26.6	47.3	73.6	106.0	145.0	189.0
45	103.9	81.8	.78	3.13	7.03	12.5	28.2	50.1	78.2	113.0	153.0	200.0
50	115.5	86.25	.83	3.30	7.41	13.2	29.7	52.8	85.5	119.0	162.0	211.0
55	127.0	90.4	.87	3.46	7.77	13.8	31.1	55.3	86.4	125.0	169.0	221.0
60	138.6	94.5	.90	3.62	8.12	14.5	32.5	57.8	90.4	130.0	177.0	231.0
65	150.1	98.3	.94	3.77	8.45	15.1	33.8	60.2	94.0	136.0	184.0	241.0
70	161.7	102.1	.98	3.91	8.78	15.7	35.2	62.5	97.7	141.0	191.0	250.0
75	173.2	105.7	1.01	4.05	9.08	16.2	36.4	64.7	101.0	146.0	198.0	259.0
80	184.8	109.1	1.05	4.18	9.39	16.7	37.6	66.8	104.0	150.0	205.0	267.0
85	196.3	112.5	1.08	4.31	9.67	17.3	38.8	68.9	108.0	155.0	211.0	276.0
90	207.9	115.8	1.11	4.43	9.95	17.7	39.9	70.8	111.0	160.0	217.0	284.0
95	219.4	119.0	1.14	4.56	10.2	18.2	41.0	72.8	114.0	164.0	223.0	292.0
100	230.9	122.0	1.17	4.67	10.05	18.7	42.1	74.7	117.0	168.0	229.0	299.0

¹ The actual quantities will vary from the figures in this table, depending on the shape of the nozzle and the size of the pipe at the point where the pressure is determined. With smooth-taper nozzles the actual discharge is about 94 percent of the figures given in the table above.

Table 13-5. Suction Lift of Pumps at Various Altitudes

Altitude above sea level		Barometric pressure (pounds per square inch)	Equivalent head of water (feet)	Practical suction lift of pump (feet)
Feet	Miles			
0	0	14.70	33.95	25
1,320	¼	14.02	32.38	24
2,640	½	13.33	30.79	23
3,960	¾	12.66	29.24	21
5,280	1	12.02	27.76	20
6,600	1¼	11.42	26.38	19
7,920	1½	10.88	25.13	18
10,560	2	9.88	22.82	17

Table 13-6. Relative Equivalent Quantities of Water Delivered

Gallons in 1 minute	Gallons in 1 hour	Gallons in 24 hours	Gallons in 1 minute	Gallons in 1 hour	Gallons in 24 hours	Gallons in 1 minute	Gallons in 1 hour	Gallons in 24 hours
3.4	208	5,000	138.8	8,333	200,000	486.1	29,166	700,000
6.9	416	10,000	173.6	10,416	250,000	520.8	31,250	750,000
10.4	625	15,000	208.3	12,500	300,000	555.5	33,333	800,000
13.8	833	20,000	243.0	14,583	350,000	590.2	35,416	850,000
17.3	1,041	25,000	277.7	16,666	400,000	625.0	37,500	900,000
34.7	2,083	50,000	312.5	18,750	450,000	659.7	39,583	950,000
41.6	2,500	60,000	347.2	20,833	500,000	694.3	41,666	1,000,000
52.9	3,125	75,000	381.9	22,916	550,000	1,041.7	62,500	1,500,000
69.4	4,166	100,000	416.7	25,000	600,000	1,388.0	83,333	2,000,000
104.1	6,250	150,000	451.3	27,083	650,000	1,736.0	104,166	2,500,000

Table 13-7. Rate of Flow Equivalents

Units	Cubic feet per second	Cubic feet per minute	U.S. gallons per minute	U.S. gallons per 24 hr.
1 cubic foot per second equals	1.0	60.0	448.83	646,317.0
1 cubic foot per minute equals	0.02	1.0	7.48	10,771.9
1 U.S. Gallon per minute equals	0.002	0.13	1.0	1,440.0
1 U.S. gallon per 24 hours equals	1.55×10^{-4}	9.28×10^{-5}	0.0007	1.0
1 British Imperial gallon per minute equals	0.003	0.16	1.20	1,729.37
1 liter per minute equals	0.0006	0.03	0.26	380.42
1 acre-foot per hour equals	12.1	726.0	5,430.86	7,820,434.0
1 acre-foot per 24 hours equals	0.50	30.25	226.2	325,851.0

Units	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hr.
1 cubic foot per second equals	373.3	1,698.98	0.083	1.98
1 cubic foot per minute equals	6.23	28.32	0.001	0.03
1 U.S. gallon per minute equals	0.83	3.78533	0.0001841	0.0044192
1 U.S. gallon per 24 hours equals	0.000	0.003	1.28×10^{-7}	3.07×10^{-5}
1 British Imperial gallon per minute equals	1.0	4.55	0.0002	0.005
1 liter per minute equals	0.22	1.0	4.86×10^{-5}	0.001
1 acre-foot per hour equals	4,522.13	20,557.6	1.0	24.0
1 acre-foot per 24 hours equals	188.42	856.57	0.04	1.0

Note. Negative exponents to the number 10 indicate the number of decimal places to the right of the decimal point, i.e.: $10^{-6} = 0.000001$; $10^{-4} = 0.001$; $1.55 \times 10^{-4} = 0.0000155$.

Table 13-8. Volume and Capacity Equivalents

Units	U.S. gallons	British Imperial gallons	Liters
1 U.S. gallon equals	1.0	0.83	3.78
1 British Imperial gallon equals	1.20	1.0	4.55
1 liter equals	0.26	0.22	1.0
1 cubic foot equals	7.48	6.23	28.32
1 cubic inch equals	4.33	3.6×10^{-3}	0.02
1 acre-foot equals	325,851.0	271,328.0	1,233,456.0
1 inch deep on 1 acre equals	27154.3	22,610.6	102,788.0
1 inch deep on 1 square mile equals	17,378,743.0	14,470,801.0	65,784,344.0
1 meter deep on 1 hectare equals	2,641,705.0	2,199,675.0	9,999,734.0
1 centimeter deep on 1 square meter equals	2.64	2.20	10.0
1 pound of water at 39.2° F. equals	0.02	0.10	0.45
1 pound of water at 50° F. equals	0.12	0.10	0.45
1 pound of water at 62° F. equals	0.12	0.10	0.45
1 U.S. gallon per minute for 24 hours equals	1,440.0	1,199.05	5,450.88
1 cubic foot per minute for 24 hours equals	10,771.9	8,969.50	40,775.4

Table 13-8. Volume and Capacity Equivalents—Continued

Units	Cubic feet	Cubic inches	Acre-feet
1 U.S. gallon equals	0.13	231.0	3.07×10^{-6}
1 British Imperial gallon equals	0.16	277.42	3.69×10^{-6}
1 liter equals	0.03	61.02	8.11×10^{-7}
1 cubic foot equals	1.0	1,728.0	2.296×10^{-5}
1 cubic inch equals	5.79×10^{-5}	1.0	1.33×10^{-8}
1 acre-foot equals	43,560.0	75,271,680.0	1.0
1 inch deep on 1 acre equals	3,630.0	6,272,640.0	0.08
1 inch deep on 1 square mile equals	2,323,200.0	4,014,489,600.0	5.33
1 meter deep on 1 hectare equals	353,145.0	610,233,780.0	8.10708
1 centimeter deep on 1 square meter equals	0.35	610.23	8.11×10^{-6}
1 pound of water at 39.2° F. equals	0.02	27.68	3.69×10^{-7}
1 pound of water at 50° F. equals	0.02	27.69	3.68×10^{-7}
1 pound of water at 62° F. equals	0.02	27.71	3.68×10^{-7}
1 U.S. gallon per minute for 24 hours equals	192.5	332,640.0	0.004
1 cubic foot per minute for 24 hours equals	1,440.0	2,448,320.0	0.03

Note. Negative exponents to the number 10 indicate the number of decimal places to the right of the decimal point, i.e.: $10^{-6} = 0.000001$; $10^{-3} = 0.001$; $1.55 \times 10^{-4} = 0.0000155$.

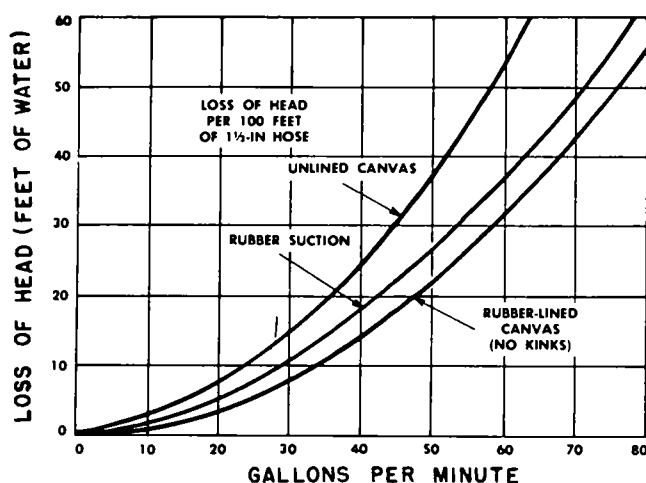


Figure 13-4. Loss of head in 1½-inch hose.

13-9. Vertical Cylindrical Tank Capacities

Capacities per foot of depth for vertical cylindrical tanks 1 foot to 100 feet in diameter are shown in table 13-9. Capacities per inch of depth may be computed by dividing the values shown by 12.

13-10. Coagulation and Adjustment of Alkalinity

Table 13-10 lists the chemicals and quantities required for use as coagulants and to adjust the alkalinity in water.

13-11. Water Supply and Distribution Systems

a. *General.* A water system consists of a well, spring, river, lake, reservoir, or other water source; the treatment plant, pump, ground or elevated storage tanks, supply lines, or other production and treatment facilities; and the distribution lines which convey the approved water to the various outlets.

b. Description.

(1) *Basic systems.* There are three basic types of water supply and distribution systems.

(a) Gravity flow, where the source is at sufficient elevation above the outlets to transport the water without pumping.

(b) Direct pumping, where water from the source is pumped directly into the system with or without a pressure tank to absorb differences between pumping and usage rates.

(c) A combination of gravity and pumping, where water from the source is pumped to an elevated storage tank and from there distributed to the outlets by gravity.

(2) Pipes.

(a) *Classification.* The network of pipes should be arranged so that large primary mains feed smaller secondary pipes. Mains carry water from the source to the service pipes. Service pipes carry water from the main to the building.

(b) *Arrangement.* A distribution system is constructed either as a dead-end system or as a loop system. In a dead-end system a single

Table 13-9. Vertical Cylindrical Tank Capacities

Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth	Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth
1' 0"	0.785	5.87	6'	28.27	211.5
1' 1"	0.922	6.89	6' 3"	30.68	229.5
1' 2"	1.069	8.00	6' 6"	33.18	248.2
1' 3"	1.227	9.18	6' 9"	35.78	267.7
1' 4"	1.396	10.44	7'	38.48	287.9
1' 5"	1.576	11.79	7' 3"	41.28	308.8
1' 6"	1.767	13.22	7' 6"	44.18	330.5
1' 7"	1.969	14.73	7' 9"	47.17	352.9
1' 8"	2.182	16.32	8'	50.27	376.0
1' 9"	2.405	17.99	8' 3"	53.46	399.9
1' 10"	2.640	19.75	8' 6"	56.75	424.5
1' 11"	2.885	21.58	8' 9"	60.13	449.8
2'	3.142	23.50	9'	63.62	475.9
2' 1"	3.409	25.50	9' 3"	67.62	502.7
2' 2"	3.687	27.58	9' 6"	70.88	530.2
2' 3"	3.976	29.74	9' 9"	74.66	558.5
2' 4"	4.276	31.99	10'	78.54	587.5
2' 5"	4.587	34.31	10' 6"	86.59	647.7
2' 6"	4.909	36.72	11'	95.03	710.9
2' 7"	5.241	39.21	11' 6"	103.9	777.0
2' 8"	5.585	41.78	12'	113.1	846.0
2' 9"	5.940	44.43	12' 6"	122.7	918.0
2' 10"	6.305	47.16	13'	132.7	992.9
2' 11"	6.681	49.98	13' 6"	143.1	1,071.0
3'	7.069	52.88	14'	153.9	1,152.0
3' 1"	7.467	55.86	14' 6"	165.1	1,235.0
3' 2"	7.867	58.92	15'	176.7	1,322.0
3' 3"	8.296	62.06	15' 6"	188.7	1,412.0
3' 4"	8.727	65.28	16'	201.1	1,504.0
3' 5"	9.168	68.58	16' 6"	213.8	1,600.0
3' 6"	9.621	71.97	17'	227.0	1,698.0
3' 7"	10.08	75.44	17' 6"	240.5	1,799.0
3' 8"	10.56	78.99	18'	254.5	1,904.0
3' 9"	11.04	82.62	18' 6"	268.8	2,011.0
3' 10"	11.54	86.33	19'	283.5	2,121.0
3' 11"	12.05	90.13	19' 6"	298.6	2,234.0
4'	12.57	94.00	20'	314.2	2,350.0
4' 1"	13.10	97.96	20' 6"	330.1	2,469.0
4' 2"	13.64	102.0	21'	346.4	2,591.0
4' 3"	14.19	106.1	21' 6"	363.1	2,716.0
4' 4"	14.75	110.3	22'	380.1	2,844.0
4' 5"	15.32	114.6	22' 6"	397.6	2,947.0
4' 6"	15.90	119.0	23'	415.5	3,108.0
4' 7"	16.50	123.4	23' 6"	433.7	3,245.0
4' 8"	17.10	128.0	24'	452.4	3,384.0
4' 9"	17.72	132.6	24' 6"	471.4	3,527.0
4' 10"	18.35	137.3	25'	490.9	3,672.0
4' 11"	18.99	142.0	25' 6"	510.7	3,820.0
5'	19.63	146.9	26'	530.9	3,972.0
5' 3"	21.65	161.9	26' 6"	551.5	4,126.0
5' 6"	23.76	177.7	27'	572.6	4,283.0
5' 9"	25.97	94.3	27' 6"	594.0	4,443.0

Table 13-9. Vertical Cylindrical Tank Capacities—Continued

Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth	Diameter	Cu ft per 1' of depth	U.S. gallons per 1' of depth
28'	615.8	4,606.0	52'	2,124.0	14,890.0
28' 6"	637.9	4,772.0	54'	2,290.0	17,130.0
29'	660.5	4,941.0	56'	2,463.0	18,420.0
29' 6"	683.5	5,113.0	58'	2,642.0	19,760.0
30'	706.9	5,288.0	60'	2,827.0	21,150.0
31'	754.8	5,646.0	62'	3,019.0	22,380.0
32'	804.3	6,016.0	64'	3,217.0	24,060.0
33'	855.3	6,398.0	66'	3,421.0	25,590.0
34'	907.9	6,792.0	68'	3,632.0	27,170.0
35'	962.1	7,197.0	70'	3,488.0	28,790.0
36'	1,018.0	7,616.0	72'	4,072.0	30,450.0
37'	1,075.0	8,043.0	74'	4,301.0	32,170.0
38'	1,134.0	8,483.0	76'	4,536.0	33,930.0
39'	1,195.0	8,940.0	78'	4,778.0	35,740.0
40'	1,257.0	9,404.0	80'	5,027.0	37,600.0
41'	1,320.0	9,876.0	82'	5,281.0	39,500.0
42'	1,385.0	10,360.0	84'	5,542.0	41,540.0
43'	1,452.0	10,860.0	86'	5,809.0	43,450.0
44'	1,521.0	11,370.0	88'	6,082.0	45,490.0
45'	1,590.0	11,900.0	90'	6,362.0	47,590.0
46'	1,662.0	12,430.0	92'	6,648.0	49,720.0
47'	1,735.0	12,980.0	94'	6,940.0	51,920.0
48'	1,810.0	13,540.0	96'	7,238.0	54,140.0
49'	1,886.0	14,110.0	98'	7,543.0	56,420.0
50'	1,964.0	14,690.0	100'	7,854.0	58,750.0

Table 13-10. Chemicals Used to Coagulate or Adjust Alkalinity of Water

Chemical	How to use	How shipped	Weight (pounds per cubic foot)	Effective pH range	Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant	Artificial alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant			Remarks
						Hydrated lime	Quick-lime	Soda ash	
Alum—Al ₂ (SO ₄) ₃ 18 H ₂ O.	Coagulant.	100-pound bags. 200-pound bags. 400-pound barrels. Bulk.	39	4.4 to 6.0 5.7 to 8.0 9.0 to 10.5	0.45	0.35	0.28	0.48	4.4 to 6.0 pH range used for highly colored water. 5.7 to 8.0 pH range used for turbid and moderately colored water. 9.0 to 10.5 pH range used in alum coagulation of carbonates in lime-soda softening.
Ammonia alum Al ₂ (SO ₄) ₃ (NH ₄) ₂ SO ₄ 24 H ₂ O.	Coagulant.	400-pound bags. 100-pound kegs.	39 ± . .	5.7 to 8.0	0.29 ±	0.23 ±	0.18 ±	0.31 ±	Less soluble than filter alum and weighs 1½ times as much in terms of aluminum oxide content. Use generally restricted to pressure filters incorporating an "alum pot" or in batch coagulation. Ammonia available for formation of chloramines.

Table 13-10. Chemicals Used to Coagulate or Adjust Alkalinity of Water—Continued

Chemical	How to use	How shipped	Weight (pounds per cubic foot)	Effective pH range	Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant	Artificial alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant			Remarks
						Hydrated lime	Quick- lime	Soda ash	
Sulfuric acid— H_2SO_4 .	To ad- just pH in con- nection with coagu- lation.	10-gallon carboys. 500-pound steel drums. 93%. 1,500-pound steel H_2SO_4 drums.	Liquid: 18 pounds per gallon	-----	-----	-----	-----	-----	Always dilute by adding acid to water, otherwise serious burns may result. Can be fed by use of hypochlorite- solution equipment.
Sodium aluminate $Na_2Al_2O_4$.	Coagul- ant.	Solid: 108-pound thin- steel drums. 405-pound thin- steel drums. 100-pound bags. Liquid: 32% $Na_2Al_2O_4$ — steel drums 10% NaOH.	58 ± ----	6.0 to 7.5 (with alum).	-----	-----	-----	-----	Used with alum to assist in the coagulation of cold wa- ter. Also used with alum to coagulate alkaline waters, such as with water soften- ing. Supplies alkali as well as aluminum. Commercial grade contains 55% alum- inum oxide and 35% com- bined soda plus 6% excess caustic soda.
Copperas (ferrous sulfate)— $FeSO_4$.	Coagul- ant.	100-pound bags. 200-pound bags. 400-pound barrels. Bulk.	46 ± ----	8.5 to 11.0	-----	0.27	0.22	(¹)	
Chlorinated copperas.	Coagul- ant.	See cop- peras.	See Cop- peras.	3.5 to 9.5	0.85	0.65	0.52	(¹)	Chlorine added to copperas. One pound of chlorine re- quired for each 7.8 pounds of copperas used.
Ferric sul- fate— $Fe_2(SO_4)_3$.	Coagul- ant.	200-pound bags. 400-pound wooden barrels.	70 -----	3.5 to 9.5	0.78	0.58	0.42	(¹)	If dry-feed machine is used, must have solution pot feeding two parts water to each part of ferric sulfate. Used with lime for iron and manganese removal.
Ferric chloride— $FeCl_3$.	Coagul- ant.	Liquid: 12-gallon car- boys. 42%. 8,000-	-----	3.5 to 9.5	0.92	0.72	0.58	(¹)	Very corrosive. Rubberlined equipment must be used. Use with lime for iron and manganese removal. Use with pulverized limestone to coagulate turbid and

¹ Not normally used.

Table 13-10. Chemicals Used to Coagulate or Adjust Alkalinity of Water—Continued

Chemical	How to use	How shipped	Weight (pounds per cubic foot)	Effective pH range	Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant	Artificial alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant			Remarks
						Hydrated lime	Quick- lime	Soda ash	
		gallon rubber- lined tank cars. 42%. Crystals: 55-gallon hard- wood barrels, each con- taining 435 pounds. 60%. Anhydrous: 100 one pound bags per steel drum. 95 % ferric chlor- ide.							colored waters.
Soda ash— Na_2CO_3 .	To ad- just pH, aid coag- ula- tion. or re- move perma- nent hard- ness.	100-pound bags. 200-pound bags. 400-pound barrels. Bulk.	63 .....	.....	.....	.....	.....	.....	Readily soluble and non-cor- rosive to wrought-iron or lead piping. May be used to prevent corrosion when hardness of water exceeds about 40 quarts per mil- lion.
Hydrated lime— Ca_2 $(\text{OH})_2$.	To ad- just pH, aid coag- ula- tion, or re- move carbo- nate hard- ness.	50-pound paper bags.	50 .....	.....	.....	.....	.....	.....	Only slightly soluble and thus is fed as a suspension. Cheaper and more effective than soda ash. Used to pre- vent corrosion irrespective of hardness of water.

Table 13-10. Chemicals Used to Coagulate or Adjust Alkalinity of Water—Continued

Chemical	How to use	How shipped	Weight (pounds per cubic foot)	Effective pH range	Natural alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant	Artificial alkalinity required in grains per gallon to react with 1 grain per gallon of coagulant			Remarks
						Hydrated lime	Quick- lime	Soda ash	
Quick lime— CaO.	To ad- just pH, aid coag- ula- tion, or re- move carbo- nate hard- ness.	Wooden barrels, metal drums, water proof bags. Bulk.	65	-----	-----	-----	-----	-----	Must be slaked before used. Somewhat cheaper and more effective than hydra- ted lime, but difficulty of handling limits its use to large plants.
Pulverised limestone —94% CaCO ₃ .	Adjust pH and/or aid coag- ula- tion.	80-pound bags or bulk.	100	-----	-----	-----	-----	-----	May be added as batch or fed with dry or slurry feeders. Particularly useful in sol- ids, contact reactors.

distribution main runs from the pump or elevated storage tank to the various outlets. In a loop system the distribution main forms a single loop or a series of loops with both ends connected to the pump or elevated storage tank. The advantage of a dead-end system is the economy in length of main. The advantages of a loop system are the equal delivery capacity with smaller mains, a more uniform pressure, and the ability to make repairs with a minimum of outlets deactivated. Complete loop systems are seldom used in field installations.

(c) *Design and construction.* The design of a distribution system is based on the known requirements and physical data obtained from reconnaissance, surveys, and maps. TM 5-302 includes standard layouts.

13-12. Equipment for Purification and Treatment

a. The following sets are now standard:

(1) Water purification equipment set, diatomite filter, 420 GPH, is air droppable, and transportable by helicopter and $\frac{3}{4}$ ton truck; designed primarily for airmobile units.

(2) Water purification equipment set, trailer mounted, diatomite filter, 600 GPH; designed primarily for use by airborne units.

(3) Water purification equipment set, truck mounted, diatomite filter 1,500 GPH; primarily for use with combat units.

(4) Water purification equipment set; truck mounted, diatomite filter, 3,000 GPH; issued to engineer water purification teams.

(5) Water purification plant, for fixed or permanent installations, coagulation and rapid sand filter, 10,000 GPH.

(6) Seawater distillation unit, vapor-compression type, all aluminum, trailer-mounted, 150 GPH.

b. *Use of Existing Facilities.* In cities or communities where water supply and treatment plants have existed, it may be practicable to use those facilities. A damaged treatment plant can often be operated by reducing the rate of treatment, or by omitting some part of the treatment process (with the exception of disinfection) until repairs are made. Sometimes, operations which had been performed automatically will have to be performed manually for a period of time to get a system in operation. Existing facilities, even if obviously damaged, should be inspected for possible utilization. Water treatment plants may vary depending upon the nature of the raw water, and the water requirements. Figure 13-5 is a schematic diagram showing the components

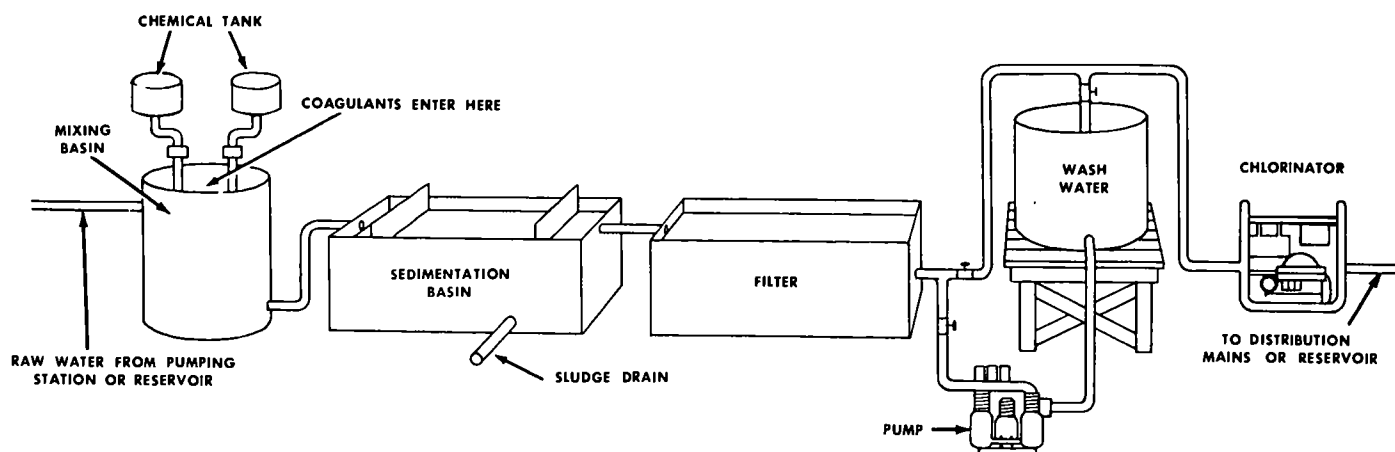


Figure 13-5. Flow diagram for typical water treatment plant.

and water flow in a typical water treatment plant.

c. References cited in paragraph 13-1 include details of construction for the various elements of the typical system.

13-13. Calculating Chlorine Requirements

a. *Chlorine dosage.* Dosage is the amount of chlorine required to satisfy chlorine demand as well as to provide a certain residual after a specified time. The chlorine demand varies with the organic content and pH value of the water, and temperature of the water at time of contact. The requirement for chlorine residual is established by medical personnel and may vary depending upon the water source, environmental conditions, and other factors. The chlorine demand test is used as a guide in determining the amount of chlorine or calcium hypochlorite needed to treat a given water. Briefly, the test consists of adding a measured dosage of chlorine to a measured quantity of the water to be treated. After a contact time of 30 minutes, the chlorine residual is read by means of the comparator. Required dosage is then computed; it is the chlorine needed to equal the sum of the demand plus the minimum required residual. It is usually stated in parts per million (PPM).

b. *Formula.*

$$(1) \text{ Lb of Cl}_2 = \frac{\text{Gal of H}_2\text{O} \times 8.3 \times \text{PPM}}{1,000,000}$$

$$(2) \text{ Lb of Cl}_2 = \text{pounds of chlorine}$$

$$(3) 8.3 = \text{weight in pounds of one gallon of water}$$

(4) PPM = the actual dosage of chlorine in parts per million (PPM)

(5) 1,000,000 = a constant

c. *Illustrative Problems.*

(1) If 8 PPM chlorine are required for 3,000 gallons of water, how many pounds of chlorine will be required?

$$\begin{aligned} \text{Lb of Cl}_2 &= \frac{3,000 \times 8.3 \times 8}{1,000,000} \\ &= 0.1992 \text{ or } 0.20 \text{ lb of chlorine} \end{aligned}$$

(2) There are 4.15 pounds of chlorine on hand and the average treatment dosage has been 5 PPM chlorine. How many gallons of water can be treated before the chlorine is exhausted?

$$\begin{aligned} \text{Gal of H}_2\text{O} &= \frac{\text{lb of Cl}_2 \times 1,000,000}{8.3 \times \text{PPM}} \\ &= \frac{4.15 \times 1,000,000}{8.3 \times 5} \\ &= 100,000 \text{ gal of H}_2\text{O} \end{aligned}$$

(3) If 16.6 pounds of chlorine were added accidentally to 20,000 gallons of water, how many PPM chlorine are present?

$$\begin{aligned} \text{PPM} &= \frac{\text{lb of Cl}_2 \times 1,000,000}{\text{gal of H}_2\text{O} \times 8.3} \\ &= \frac{16.6 \times 1,000,000}{20,000 \times 8.3} \\ &= 100 \text{ PPM chlorine} \end{aligned}$$

13-14. Calculating Calcium Hypochlorite Requirements

a. *Formula.*

$$(1) \text{ Oz Ca (OCl)}_2 = 22.9 \times \text{lb Cl}_2$$

$$(2) \text{ Oz} = \text{ounces of calcium hypochlorite}$$

(3) Ca (OCl)_2 = the chemical symbol for calcium hypochlorite

(4) 22.9 = a constant—it takes 22.9 ounces of calcium hypochlorite to equal 1 pound of pure chlorine gas.

b. Illustrative Problem. It has been determined that 0.5 pounds of chlorine will be required to treat a water source. How many ounces of Ca (OCl)_2 will be required?

$$\begin{aligned}\text{Oz Ca (OCl)}_2 &= \text{lb of Cl}_2 \times 22.9 \\ &= 0.5 \times 22.9 \\ &= 11.45 \text{ oz of Ca (OCl)}_2\end{aligned}$$

13-15. Water Demands

a. General. Delivery of water through a distribution system must be continuous and in sufficient quantity to meet the maximum rate of demand (peak demand).

b. Peak Demand for a System. The size of a water main serving an area depends on the total peak demand for that area. Service connections and mains are made large enough to deliver the total peak demand under the available pressure. Figure 13-6 gives the peak demand, in gallons per minute, in terms of the number of fixtures served by the main.

c. Fire-Protection Demand. In temporary installations it may be impracticable to construct distribution systems large enough to meet the demand of firefighting equipment. In such cases it is best to provide ground storage tanks or sumps, so located that any building can be reached with not over 1,000 feet of hose. Water is pumped by fire pumper trucks or skid-mounted pumps.

13-16. Water Pressures

a. Supply Mains and Pumps. Working pressures for the supply mains vary with the equipment available. The pumps and equipment described in TM 5-343 are designed for maximum pumping pressures of 200 to 400 psi. High pump pressure permits the use of smaller pipe without reducing the supply-main capacity. However,

pressure must be multiplied by about 4 to double the capacity of a main, whereas doubling the cross-sectional area of the main accomplishes about the same result. It is materially more economical to operate and maintain pumps and pipes at 100 to 150 psi than at higher pressures.

b. Distribution. Pressures in distribution mains are held down—by pressure-reducing valves, if necessary—to avoid exceeding the allowable pressure at outlets. This allowable pressure is established to minimize faucet leakage, wear and tear on faucets and fixtures, and water-hammer damage. It is usually set at between 20 and 75 psi and as near 20 psi as will prevent outlet pressures from falling below 20 psi at a time of peak demand. A valved bypass around the reducing valve permits any temporary pressure increase needed for firefighting.

c. Characteristics of Pipes. Table 13-11 gives dimensions, weights, and other data on standard steel and other pipes in ordinary use. See also table 14-16. For friction losses, see paragraph 13-17. For comparative discharge capacities, see paragraph 13-19.

13-17. Friction Losses

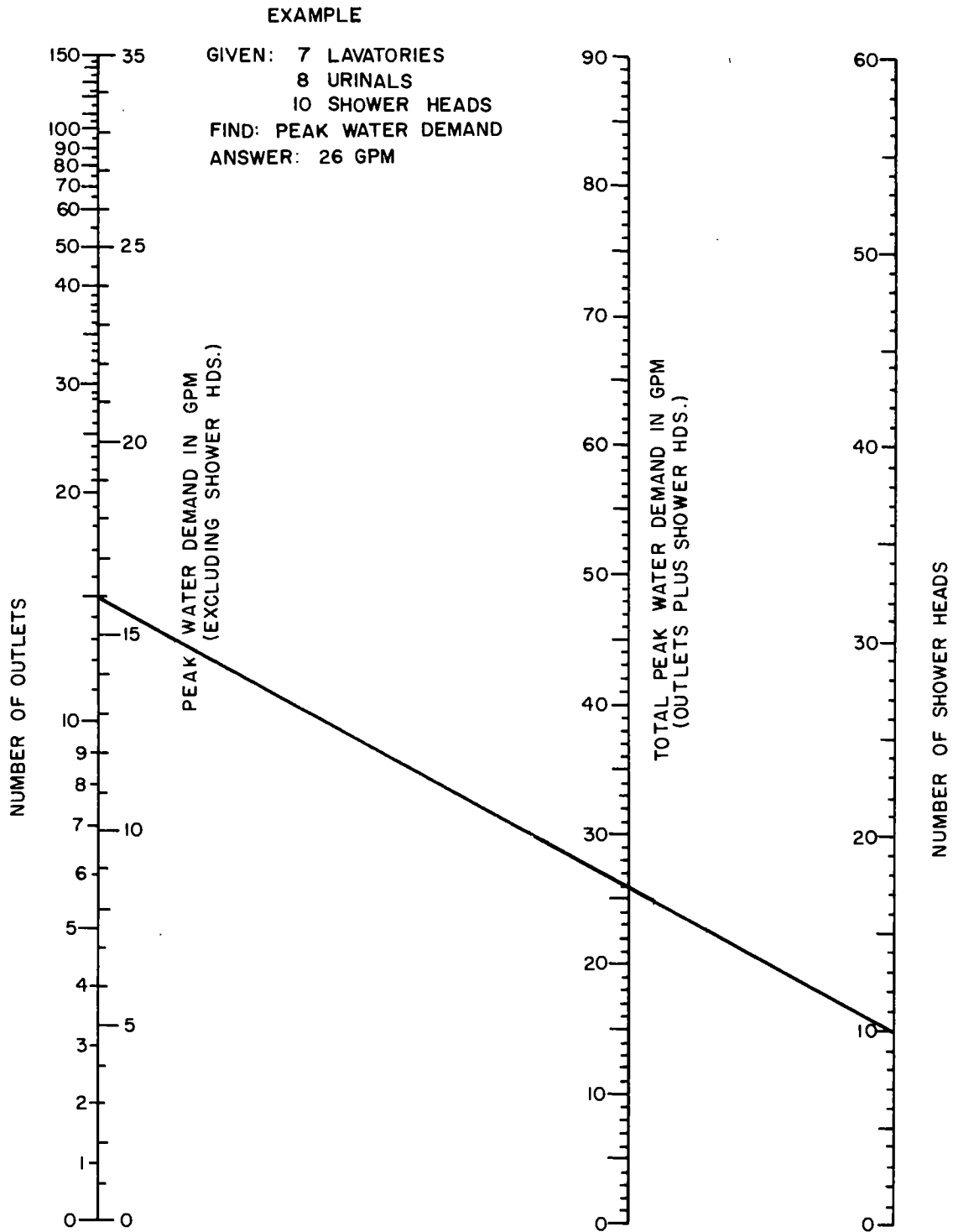
Friction losses in service connections and distribution mains may be calculated using the Hazen-Williams formula ($V = 1.318 \text{ CR}^{.63} \text{S}^{.54}$ or $Q = .006756 \text{ CD}^{2.63} \text{H}^{.54}$). Table 13-11 gives properties of pipelines of different materials, and includes the friction coefficient of each type for use in the formula. Figure 13-7 can be used for calculating pipe size, discharge, and head loss. Figure 13-8 is used for determining friction in valves and fittings.

13-18. Fixtures

Tables 13-12, 13-13, and 13-14 contain information on fixtures applicable to water supply systems.

13-19. Discharge Capacities

Table 13-15 gives comparative discharge capacities of various size water pipes.



NOMOGRAPH FOR TOTAL PEAK WATER DEMANDS

Figure 13-6. Peak water demands.

Tables 13-11. Properties of Pipeline Materials

Item	Normal sizes				Physical properties									
	Length (ft)	Diameter (in.)	Friction ¹ coeff. C	Working press (psi)	Weight per lin ft (lb)									
					¾	2	4	6	8	12	18	24	36	48
Cast iron	12	4 to 84	140 (now) to 100 (old).	Class A, 50	----	----	19.2	30.0	42.9	73.3	----	----	----	----
				Class B, 100	----	----	19.2	30.0	42.9	73.3	----	----	----	----
				Class C, 150	----	----	19.2	30.0	42.9	77.9	----	----	----	----
				Class D, 200	----	----	19.2	30.0	42.9	83.8	----	----	----	----
Steel, API	20	4, 6, 8	140	1,400 (4")	----	----	----	----	----	----	----	----	----	----
				1,300 (6")	----	----	----	----	----	----	----	----	----	----
				950 (8")	----	----	----	----	----	----	----	----	----	----
Steel, pipeline tubing	20	4, 6	140	650	----	----	4.8	10.9	16.2	----	----	----	----	----
Steel, seamless or weld	20	¾, 1½, 2 4, 6, 8	140	Std	1.1	3.7	10.9	19.2	28.8	50.7	----	----	----	----
				Extrastrong	1.5	5.0	15.0	28.6	43.4	65.4	----	----	----	----
Wrought iron	20	¾, 2, 4, 6, 8	130 to 140	Std	1.1	3.7	10.9	19.2	28.8	50.7	----	----	----	----
				Extrastrong	1.5	5.0	15.0	28.6	43.4	65.4	----	----	----	----
Wood, bonded	6-16	4, 6, 8, 12	120	45	----	----	5.8	8.7	11.2	17.7	28.8	41.4	----	----
Bituminized fiber	8 (4"), 5 (6", 8")	4, 6, 8	150	----	----	----	----	----	----	----	----	----	----	----
Asbestos cement	10	2 to 3½	140	50	----	----	4.7	7.6	11.7	19.8	35.9	55.5	126	----
	13	4, 6, 10, 12	100	100	----	----	5.0	7.8	11.9	27.6	58.2	99.3	211	----
		14, 16, 18, 20	150	150	----	----	6.0	10.7	16.8	38.6	81.2	141	318	----
		24, 30, 36	200	200	----	----	8.4	15.4	23.7	49.6	112	199	435	----
Concrete, sewer	2, 2.5, 3, 4	4 to 24	130 to 140	----	----	----	----	25	35	60	120	225	----	----
Concrete sewer, reinforced	1	12 to 100	130 to 140	----	----	----	----	----	----	100	160	260	450	720
Concrete culvert, reinforced	3	12 to 100	130 to 140	----	----	----	----	----	----	100	160	320	520	850
Concrete culvert, extra strong	3	24 to 100	130 to 140	----	----	----	----	----	----	----	----	320	520	850
Clay, sewer	2, 2.5, 3	4 to 36	110	----	----	----	8.0	14.5	23.0	43.5	96.0	172	370	----
Clay, culvert	2, 3	6 to 36	----	----	----	----	----	15.5	24.0	55.5	116	218	505	----
Corr. metal:														
16 ga	2	8 to 84	Less than 100.	----	----	----	----	----	7.6	10.8	15.8	21.0	----	----
14 ga	----	----	----	----	----	----	----	----	9.3	13.3	19.5	26.0	37.9	50.5
12 ga	----	----	----	----	----	----	----	----	----	18.5	27.0	35.9	52.4	70.0

See footnotes at end of table.

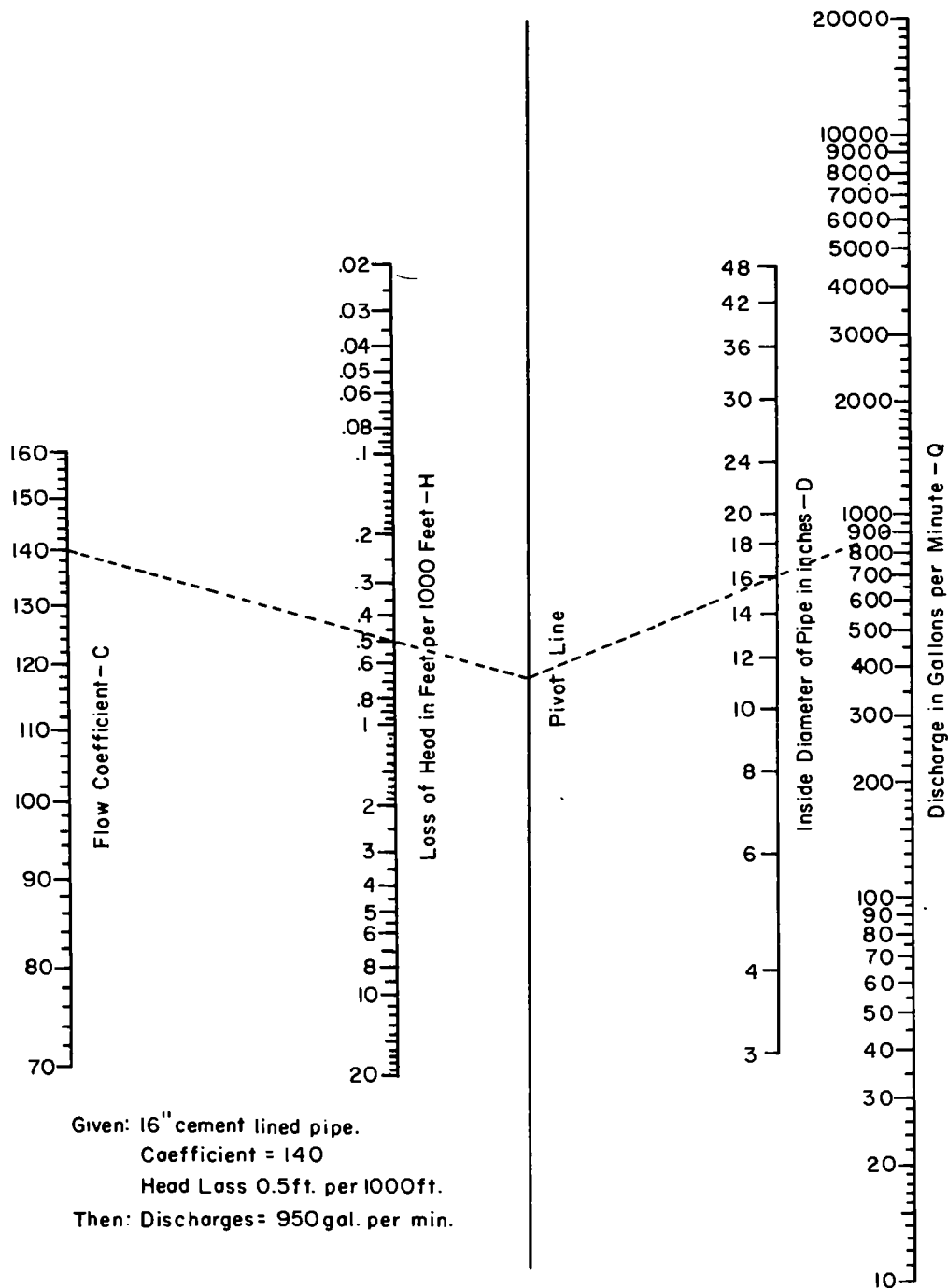
Table 13-11. Properties of Pipeline Materials—Continued

Item	Physical properties—Continued													Remarks
	Three-edge bearing strength (lb per ft)													
	4	6	8	10	12	15	16	21	24	30	36	42	48	
Cast iron														Moderately corrosion-resistant, brittle. (0.013).
Steel, API														Moderately corrosion-resistant. (0.012).
Steel pipeline tubing														Mildly corrosion-resistant, semiflexible.
Steel, seamless or weld														
Wrought iron														Corrosion-resistant ductile. (0.011).
Wood, bonded														Noncorrosive.
Bituminized fiber														Noncorrosive, semiflexible, also perforated in 4" size. (0.010).
Asbestos cement	1,740	1,420		2,580 3,690 4,920	2,370 3,850 5,100		2,030 4,140 5,360 6,340		2,340 4,650 7,050 8,600	2,980 3,000 6,180 10,450	3,500 5,400 9,700 12,300			Noncorrosive, lightweight, brittle. (0.012).
Concrete, sewer	1,000	1,100	1,300	1,400	1,500	1,750	2,000	2,200	2,400					Noncorrosive, brittle. (0.010–0.015).
Concrete sewer, reinforced ..					1,800	2,030	2,200	2,400	2,400	2,700	3,000	3,200	3,400	Noncorrosive, brittle.
Concrete culvert reinforced ..					2,250	2,625	3,000	3,000	3,000	3,375	4,050	4,725	5,400	Noncorrosive, brittle.
Concrete culvert extra strong									4,000	5,000	6,000	7,000	8,000	Noncorrosive, brittle.
Clay, sewer	1,000	1,000	1,000	1,100	1,200	1,400	1,700	2,000	2,400	3,200	3,900			Noncorrosive, brittle, imperv. (0.015–0.013).
Clay, culvert		2,000	2,000	2,000	2,250	2,750	3,300	3,830	4,400	5,000	6,000			Noncorrosive, brittle, imperv.
Corr. metal:														Semiflexible. (0.021) (0.017–0.019) coated.
16 ga														
14 ga														
12 ga														

¹ Hazen Williams.

Notes. Weights of concrete and corrugated metal pipe in 15", 21", 30", and 42" sizes may be interpolated from data shown. Weights or strengths of asbestos-cement pipe in 10", 14", 16", 20" and 30" sizes also may be estimated by interpolation.

Figures appearing in parenthesis in "Remarks" column are values of "n" for use with the Manning formula.



NOMOGRAM FOR CALCULATING PIPE SIZE, DISCHARGE & HEAD LOSS

The above nomogram is based on the Williams-Hazen formula: $Q = .006756 C D^{2.63} H^{.54}$
The coefficient of cement-lined Mono-Cast pipe is 140.

Figure 13-7. Alinement chart for calculating pipe size, discharge, and head loss.

EXAMPLE: DOTTED LINE SHOWS THAT RESISTANCE OF A 6" STANDARD SHORT RADIUS ELBOW IS EQUIVALENT TO 16' OF 6" STANDARD PIPE.

NOTE. FOR SUDDEN ENLARGEMENTS OR CONTRACTIONS, USE THE SMALLER DIAMETER, d , ON PIPE SIZE SCALE.

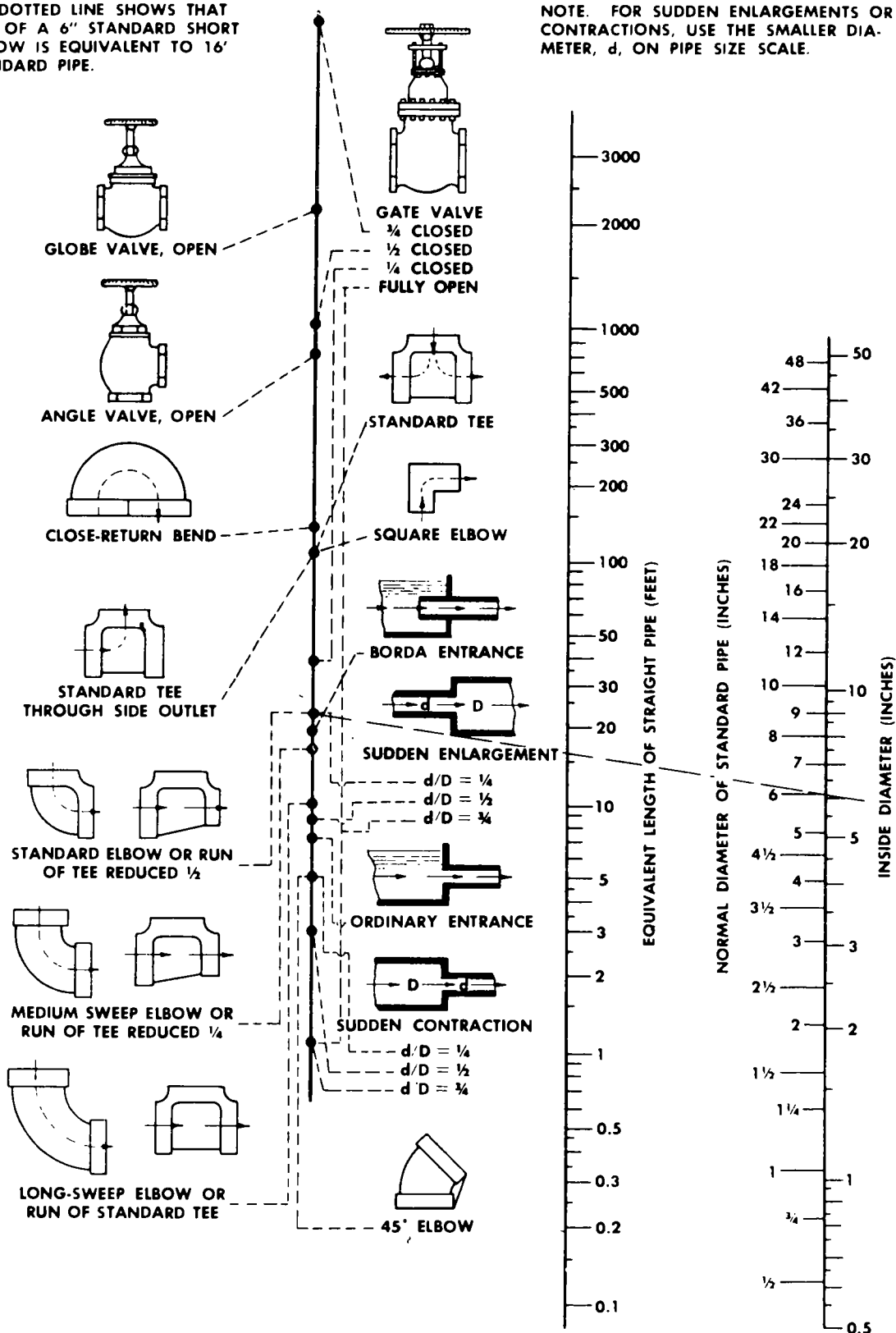


Figure 13-8. Friction chart for valves and fittings.

Table 13-12. Schedule of Fixtures per Branch

Size of branch (inches)	Connections allowed	
	Size (inches)	Number
$\frac{3}{8}$ -----	$\frac{3}{8}$	1
$\frac{1}{2}$ -----	$\frac{3}{8}$	5
$\frac{1}{2}$ -----	$\frac{1}{2}$	3
$\frac{3}{4}$ -----	$\frac{1}{2}$	8
1 -----	$\frac{1}{2}$	15
1 $\frac{1}{4}$ -----	$\frac{1}{2}$	27
1 $\frac{1}{2}$ -----	$\frac{1}{2}$	42

Table 13-13. Recommended Pipe Sizes for Fixture Branches

Fixture	Fixture branch size (inches)
Lavatory -----	$\frac{3}{8}$ for hot and cold.
Bathtub -----	$\frac{1}{2}$ for hot and cold.
Kitchen sink, small -----	$\frac{1}{2}$ for hot and cold.
Kitchen sink, large scullery -----	$\frac{3}{4}$ for hot and cold.
Laundry trays -----	$\frac{1}{2}$ for hot and cold.
Shower stall per head -----	$\frac{1}{2}$ for hot and cold.
Water closets, flush-tank -----	$\frac{3}{8}$ cold.
Water closets, flush-valve -----	1 cold.
Pedestal urinals, flush-valve -----	1 cold.
Wall type urinals, flush-valve -----	$\frac{1}{2}$ cold.

Table 13-14. Rates of Flow Through Fixtures¹

Fixture	Gallons per minute									
	1	2	3	4	6	8	10	15	20	25
Water closets with tanks.	5	10	12	15	23	26	40	50	66	75
Urinals with tanks	4	8	10	12	20	23	34	48	58	65
Water closets, flush-valve.	27	45	55	70	95	115	135	150	170	200
Urinals, flush-valve	15	25	33	45	58	75	82	88	94	100
Lavatories (based on 1 faucet).	3	5	8	10	15	18	24	33	40	48
Bathtub (based on 1 faucet).	10	18	26	32	45	56	66	90	120	150
Shower head, watersaver.	4	8	12	16	20	24	30	45	55	70
Shower head, rain type.	8	16	24	32	42	56	70	95	120	150
Kitchen sink, small (per faucet).	6	10	14	16	24	32	40	54	70	85
Kitchen sink, large (per faucet).	8	14	18	24	32	40	50	63	91	103
Service sink (per faucet).	10	18	24	28	36	44	52	68	88	110
Laundry tray (per faucet).	8	14	18	24	32	40	50	63	81	103
Drinking fountains	2	3	4	5	6	7	8	10	12	15
Hose bibbs, $\frac{1}{2}$ inch	5	8	11	14	25	34	40	60	80	100

¹ Calculated at 40 psi.

Table 13-15. Comparative Discharge Capacities of Water Pipes

Size of pipe (inches)	Number of equivalent pipes								
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	1 $\frac{1}{4}$	1 $\frac{1}{2}$	2	2 $\frac{1}{2}$	3
$\frac{3}{8}$ -----	1								
$\frac{1}{2}$ -----	1.8	1							
$\frac{3}{4}$ -----	3.6	2	1						
1 -----	6.6	3.7	1.8	1					
1 $\frac{1}{4}$ -----	13	7	3.6	2	1				
1 $\frac{1}{2}$ -----	19	11	5.3	2.9	1.5	1			
2 -----	36	20	10	5.5	2.7	1.9	1		
2 $\frac{1}{2}$ -----	56	31	16	8	4.3	2.9	2	1	
3 -----	97	54	27	15	7	5	2.8	1.8	1

Note. To find number of smaller pipes equal to a larger size, read down from smaller pipe size, across from larger size; read answer at intersection. Thus, capacity of one 2 $\frac{1}{2}$ -inch pipe equals capacity of eight 1-inch pipes.

Section II. SEWERAGE AND SEWAGE TREATMENT

13-20. References

FM 21-10, Military Sanitation, includes a chapter on waste disposal under field conditions. TM 5-665, TM 5-666, and the TM 5-814 series cover the details of sewerage and sewage treatment plants for fixed installations. TM 5-302 includes detail drawings for sewage treatment plants and layouts of sewage collection systems for military installations in the theater of operations.

13-21. Quantities of Sewage

The quantity of sewage that is disposed of varies with the number of personnel served and the restrictions placed on the use of water. Flows generally range between 15 and 50 gallons per capita per day, although permanent installations with ample water supplies may use more. The average flow from temporary installations is about 25 gallons per capita per day, and this is

increased to 50 gallons for each bed in hospitals. The peak rate of flow for short periods in the day may be three times the average rate. The curve in figure 13-9 shows the ratio of peak flow to average flow.

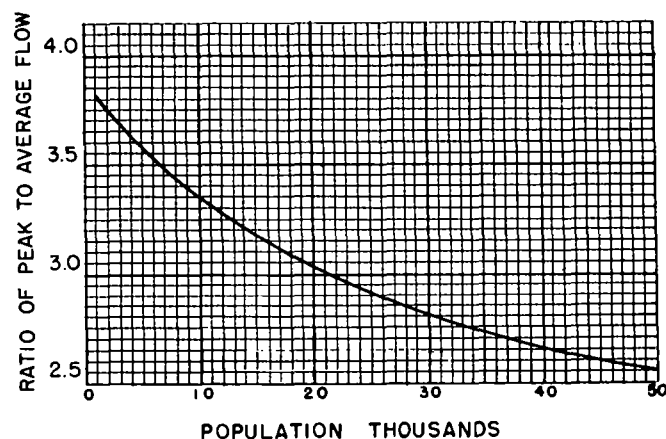


Figure 13-9. Ratio of peak to average sewage flow.

13-22. Stream Flow Required for Dilution

The amount of stream flow required for disposal by dilution depends on the strength and quantity of the sewage, the density and nearness of the population to the streambank, and the industrial or domestic use of the stream water below the outfall. A stream overloaded with sewage develops sludge banks and surface scum, is unsightly, and emits an offensive odor. For streams not used for industrial and domestic water supply below the sewage outfall, table 13-16 provides a guide in determining the quantity of sewage that may be discharged. This table gives the minimum stream flow required for dilution of raw and treated sewage. These data apply to TO conditions and may not comply with local, state, or federal requirements. If enough water is not available for dilution, oxidation ponds, leaching cesspools, or tile distribution fields are used for disposal of surplus sewage, taking adequate pre-

Table 13-16. Minimum Stream Flow Required for Dilution

Type of treatment	Dilution per 1,000 sewage-contributing population	
	Densely populated areas	Sparsely populated areas
None	20 c.f.s. and over ..	5 c.f.s. and over.
Partial (settling) ..	12 to 20 c.f.s.	3 to 5 c.f.s.
Complete	6 to 12 c.f.s.	0 to 3 c.f.s.

cautions to avoid contamination of the water supply.

13-23. Sanitary Sewers

a. Layout. To avoid deep excavations sewers are located along natural drainage lines. If possible, they are not laid longitudinally under roadways. Road crossings are kept to a minimum and where less than 4 feet of cover is available the pipe is reinforced by backfilling the lower 2 feet of the trench with low-grade concrete. In light traffic areas, sewers should be covered with at least 2 feet of well-compacted earth. Connections adjoining buildings may need only 1 foot of cover. Manholes are located at each change of direction, size, or slope and usually are placed at the end of each lateral. On straight sections of sewers, the maximum distance between manholes is 400 feet if sewer diameter is 18 inches or less, and 500 feet for larger diameter sewers. Two hundred to three hundred feet spacing is preferable, to facilitate sewer maintenance and cleaning.

b. Size. The size of sewer required to carry a given capacity depends on the slope of the sewer and the resistance to flow caused by the interior surface of the pipe. Pipes less than 4 inches in diameter (on a slope of 3/16-inch per foot) are used, because they clog and require frequent cleaning. Four-inch pipe may be used on house sewers; lateral and other sewers are 6 inches or more in diameter.

c. Velocity. To prevent the settling out of solids the minimum velocity is 2 feet per second when the sewage flow is at the full capacity of the sewer. However, in unfavorable terrain a velocity of 1.5 fps may be accepted if maintenance is considered to be less costly than initial construction. To prevent scour of the invert the maximum velocity is 10 fps when the sewer flow is at the full capacity of the sewer.

13-24. Sizes of Sewer Lines

a. Table 13-17 is based on an assumed peak load of 75 gallons per capita per day. (This is for permanent installation; in a theater of operations, use 25 gallons per day.) Flow is from Kutter's formula, using $n = 0.013$. For further information see pipe flow diagram (fig 13-10 and proportionate flow chart (fig 13-11).

b. The following examples illustrate the use of the pipe flow diagram and the proportionate flow chart as shown in figures 13-10 and 13-11.

Table 13-17. Sizes of Sewer Lines

Pipe diameter (inches)	2-f.p.s. velocity			1.5-f.p.s. velocity		
	Slope (ft. per 100 ft)	Discharge (g.p.m.)	Population capacity	Slope (ft per 100 ft)	Discharge (g.p.m.)	Population capacity
6	0.63	176	3,300	0.36	132	2,500
8	.40	314	6,000	.23	235	4,500
10	.28	490	9,000	.16	368	7,000
12	.21	707	13,000	.12	530	10,000
¹ 14	.17	960	18,000	.095	721	13,000
15	.15	1,104	21,000	.086	828	15,000
¹ 16	.14	1,260	24,000	.078	942	18,000
18	.12	1,590	30,000	.067	1,192	22,000
¹ 20	.10	1,970	37,000	.056	1,472	28,000
21	.09	2,160	41,000	.053	1,623	31,000
24	.076	2,825	54,000	.044	2,120	40,000

¹ These sizes are nonstandard sewer sizes.

(1) To determine pipe size:

Assume a peak sewage flow of 150 GPM on a 1 percent slope. Using figure 13-10 find intersection of horizontal line from 150 GPM and vertical line of 1 percent. This falls below a 6" Pipe—the 6" must be used on a trial basis. Then using a 6" pipe on a 1 percent slope the flow conditions for FULL FLOW can be found; i.e., 230 GPM capacity and 2.5 fps velocity. To find what the actual flow conditions would be, figure 13-11 must be used.

(2) To use proportionate flow chart figure 13-11 the proportionate discharge must be found by—

$$\frac{Q_{\text{Actual}}}{Q_{\text{Full Flow}}} = \frac{Q_A}{Q_F} = \frac{150}{230} = 0.65$$

By entering proportionate flow chart at 0.65 construct vertical line to discharge curve then horizontal line to velocity curve, thence straight down

and read proportional velocity $\frac{V_A}{V_F}$ as 1.06—the

actual velocity at 150 GPM will then be $1.06 \times 2.5 = 2.7\text{fps}$.

13-25. Treatment of Sewage

a. Type. If treatment is required, the type of treatment and plant depends on the quantity and type of sewage, soil conditions, receiving waters, materials and labor available, and the climate. The Army Medical Service is responsible for determining the degree of treatment required before disposal. Partial or complete treatment depends on the conditions controlling the disposal methods.

b. Site and Layout. The main consideration in selecting the treatment-plant site is the location of the final receiving ground or diluting water. The treatment plant should be downwind and far enough away from populated areas to avoid odor nuisance. Other factors influencing site selection are the elevation above floodwater level and the ground slope for gravity operation. Unless there is a 10- to 15-foot drop to provide gravity flow through complete treatment plants, the sewage is pumped. All treatment plants have a bypass for use during repair and maintenance. Plants which serve more than 5,000 persons are built generally with multiple tanks, filters, and other facilities, and the pipes are arranged so that parts of the plant can be bypassed for cleaning and repairing without putting the entire installation out of operation.

c. Capacity. Designs of tanks, basins, and other units within a treatment plant are based on the average anticipated flow for the required retention period. All pipes and channels within the plant are designed to carry the peak flow at velocities of not less than 2 feet per second.

d. Design. Standard designs for small sewage-treatment plants are shown in TM 5-302. If time and manpower are critical, as is generally the case in a theater of operations, raw sewage may be emptied into a lagoon. When primary sedimentation and sludge digestion are sufficient to meet the needs for treatment of the sewage, only the Imhoff tank and sludge-drying beds are constructed, but if complete treatment is required, the trickling filter and final settling tank are also provided. This design criterion should be followed if larger plants are required. Important factors are the contributing population, settling time,

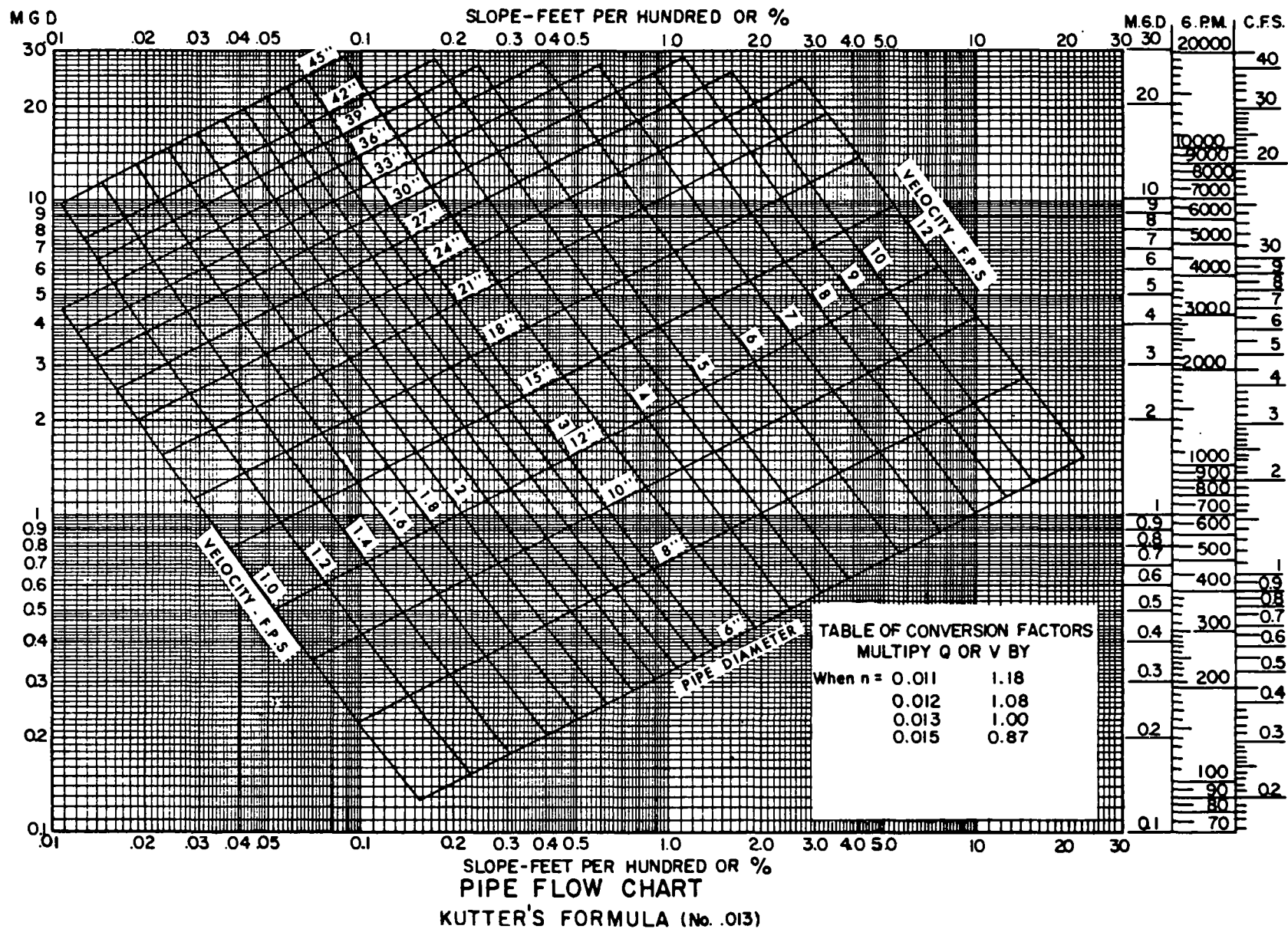


Figure 13-10. Pipe flow diagram.

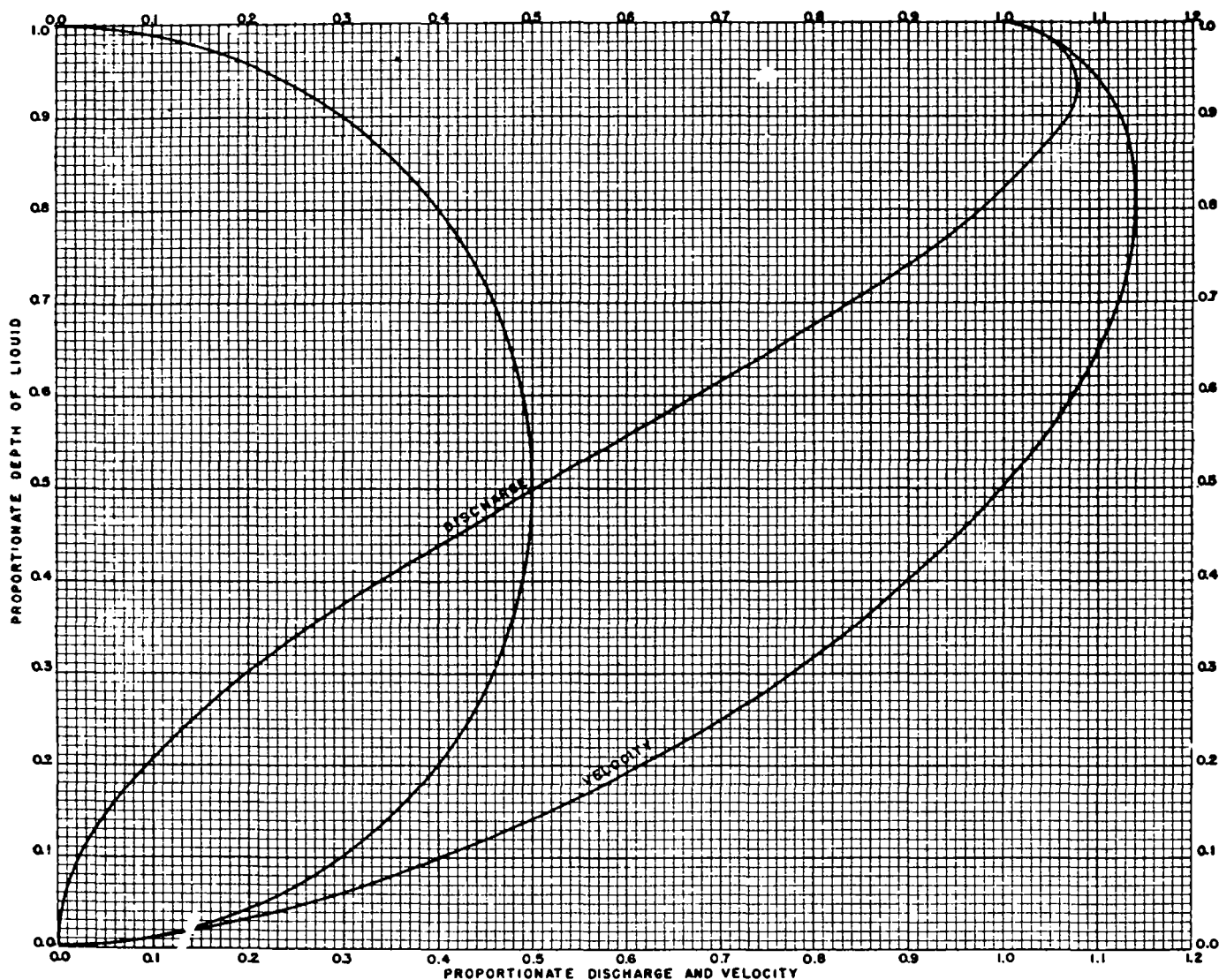


Figure 13-11. Proportionate flow chart.

filter loading, sludge-digestion capacity, and sludge-drying-bed area. The area required for sludge-drying beds with drains is $11\frac{1}{2}$ sq ft per capita; without drains it is $41\frac{1}{2}$ sq ft per capita.

13-26. Sewage and Sludge Lagoons

In its simplest form, a sewage lagoon is a large shallow pond, either natural or artificial. It is generally adequate for sewage disposal in a theater of operations. The sewage lagoon should provide approximately 1 acre of surface area per 100 people served (in a hot climate, 1 acre can serve up to 300 people), and the sewage depth should be kept between 2 feet and 5 feet for optimum results. Influent and effluent piping should be located to minimize short circuiting of sewage.

The sewage lagoon will provide excellent primary and secondary sewage treatment in most areas, except those in which the surface may freeze and remain frozen for an extended period of time. Sludge lagoons may be used for disposal of sludge from Imhoff and digestion tanks. For this purpose, sludge lagoons should be about 6 feet deep and large enough to provide a 6 month storage capacity, equal to about 4 cubic feet per capita.

13-27. Septic Tanks

Septic tanks may be used for small installations in isolated places where the soil is suitable for underground disposal, and where connection to a sewer system or discharge into a watercourse is

not practicable. TM 5-302 shows a design of a septic tank, tile field, and cesspool, and design criteria for these facilities.

13-28. Surface Irrigation

a. Rate of Application. Disposal rates (rate of application) of sewage by surface irrigation vary with the permeability of the soil, ranging as high as 60,000 gallons per acre per day. To estimate the rate of application, dig a hole 1 foot square and 1 foot deep and fill it with water. When the water has seeped away but the bottom of the hole is still wet, pour 6 inches of water in the hole and note the time required for the water level to drop 1 inch. This time in minutes corresponds to the permissible rates of sewage application shown in table 13-18 which are furnished only as a guide.

b. Ground Recovery. Ground used for surface irrigation must be rested. With use, the surface will clog and must be scraped off. Allowances for ground resting and recovery, field maintenance, and normal rainfall are included in table 13-18.

Table 13-18. Surface Irrigation; Gallons per Acre per Day

Time for water to fall 1 inch in test hole (minutes)	Average rate of application (gallons per acre per day)
1	57,700
2	46,800
5	34,800
10	25,000
30	12,000
60	8,700

13-29. Leaching Cesspools

Leaching cesspools are closed or covered pits, usually with openjointed masonry walls and an unlined bottom, through which liquids percolate into the surrounding soil. Solids settle to the bottom of the pit where they are digested. Occasionally, it may be necessary to pump or bail out the sludge. Leaching cesspools range from 4 to 6 feet in diameter and from 6 to 20 feet deep. The depth of leaching cesspools is governed by the depth of permeable soil and the groundwater level. Masonry-lined walls are laid dry with open joints to within 4 feet of the surface. If more than one cesspool is required, they are connected in series and are located at least 20 feet apart. Size can be determined by filling a 1-foot-square hole with 6 inches of water, and allowing it to seep away. While the bottom of the hole is still

wet, fill again to a depth of 6 inches and observe the time in minutes for the water in the test hole to fall 1 inch. The time in minutes is applied to the permissible rates shown in table 13-19, which are furnished only as a guide.

Table 13-19. Leaching Cesspools; Square Feet 100 Gallons Per Day

Time for water to fall 1 inch in test hole (minutes)	Required surface area of bottom and side walls in contact with sewage (square feet per 100 gallons per day)
1	19
2	23
5	31
10	44
30	91
60	111

13-30. Subsurface Irrigation

Settled sewage can be disposed of by subsurface irrigation, a method commonly used in conjunction with cesspools or septic tanks at small installations. The main distributors are laid with tight, but not necessarily waterproof, joints. The tile pipe of the laterals, usually 4 to 6 inches in diameter, is laid end to end with a 1/4-inch space between lengths. The top two-thirds of the joint is covered with roofing paper to keep the soil from washing into the line. Perforated, bituminized, fiber pipe, if available, is laid with tight end joints and perforations downward. Laterals are laid in a gravel-filled shallow trench with about a 6-inch fall per hundred feet for unregulated flow and about a 4-inch fall per hundred feet where a dosing system is used. Laterals are spaced 5 to 10 feet apart and are generally 75 to 100 feet long. To determine the length of the tile drain system, dig a 1-foot-square test hole to the depth of the proposed tile drains. Fill the hole with water to a depth of 6 inches and observe the seepage. While the bottom of the hole is still wet, fill again to a depth of 6 inches and observe the time in minutes for the water in the test hole to fall 1 inch. The time in minutes is applied to the permissible rates shown in table 13-20, which are furnished only as a guide.

13-31. Chlorination

Where the condition exists that through failure of power or equipment there is a possibility of contaminating a water supply with raw sewage, provisions are provided for chlorinating at a rate

Table 13-20. Subsurface Irrigation; Gallons Per Day Per Hundred Feet of 18-Inch Trench

Time for water to fall 1 inch in test hole (minutes)	Average rate of application (g.p.d. per 100 feet of trench 18 inches wide)
1	600
2	480
5	360
10	255
30	120
60	90

of 200 pounds per million gallons at the 4-hour peak rate of sewage flow. In other cases where chlorination is required, provisions are made for chlorination at a rate of 125 pounds per million gallons at the 4-hour peak rate of flow. The 4-hour peak rate is considered to be 175 percent of the average daily rate of flow. Chlorine is sometimes used to delay the oxygen demand until the sewage reaches a body of water large enough to provide the oxygen required. It is also effective in killing pathogens if the contact period and the chlorine concentration are sufficient, and all particles are finely enough divided to permit chlorine contact. The chlorine dosages given in table 13-21 are high and are designed to safeguard health and prevent serious nuisances in emergencies; they are not acceptable substitutes for other processes of sewage treatment. Chlorine is applied by mechanical chlorinators, chlorine contact chambers, or improvised drum chlorinators. The data given in table 13-21 are based upon obtaining a chlorine residual of 0.5 part per million after a contact time of 15 minutes.

Table 13-21. Approximate Dosage

(Pounds Liquid Chlorine Per 1,000 Persons Per Day)

Type of sewage or effluent	Approximate dosage (pounds per day liquid chlorine per 1,000 persons)
Raw sewage	40
Settled sewage	30
Trickling-filter effluent	10
Surface- or subsurface-irrigation effluent	5

13-32. Maintenance of Sewers

a. Repair. Sewer repair consists principally of replacing broken manhole covers and ring assemblies and cracked or crushed lengths of pipe. Sections of bell-and-spigot clay pipe are installed by chipping off one-half the bell of the section to be inserted, chipping off the upper portion of the

bell on the section of pipe below the gap, inserting the new section and rotating it so the unchipped half of the bell is on the bottom, and then completing the joint with mortar or mastic.

b. Methods.

(1) *Stoppages.* The clearing of stoppages is the most important item of sewer maintenance. Tree roots, particularly poplars, willows, and elms, penetrate pipe joints and clog sewers. Large objects and deposits decrease or stop flow. Sluggish flow, accumulated scum, or sewage backed up in a manhole indicates that repair or cleaning is required.

(2) *Cleaning.*

(a) Sewers are cleaned by using push rods, wooden balls, or flushing. Push rods 4 feet long are jointed and pushed through the sewer from manhole to manhole. Special tools are attached to the first rod to clear deposits or cut tree roots. The use of rods becomes difficult when the distance exceeds 300 feet.

(b) Wooden balls of one-half or three-fourths the diameter of the pipe can be used to clean deposits from sewers. They are placed in the sewer and recovered by placing a coarse screen in the manhole downstream. The sewage backed up behind the ball escapes around it at high velocity, scouring out solids deposited in the pipe.

(c) Sewers are flushed out by damming the outlet in a manhole with a sandbag, and then removing the bag with an attached rope after the manhole has partially filled. Backed-up sewage is then released to scour out deposits. Care is taken not to back up sewage into fixtures and inlets in buildings. Discarded fire hose also is used for flushing. Water pressure makes the hose stiff enough to be pushed through short lengths of pipe.

c. Safety. Sewer gas, methane, hydrogen sulfide, or gasoline and oil drainings can fill sewers with explosive mixtures. Carbon monoxide is particularly dangerous because it is often present in sewers and is not perceptible to the human senses. It may cause a slight headache preceding unconsciousness. Although some of the lighter gases are removed by opening manholes, the weight of carbon monoxide is about the same as air and it is removed only by using a blower. Sewer repair men should work in pairs, one staying above ground to observe and aid the other if necessary. A rope is sometimes tied around the man below ground to lift him out if he be-

comes unconscious. Chemical detectors for carbon monoxide are made, but if they are not available, a bird in a cage lowered into a manhole is observed for the effects of gas. A considerable

concentration of carbon monoxide makes a man unconscious almost immediately, and death is avoided only by artificial respiration, immediately and properly administered.

Section III. REFUSE COLLECTION AND DISPOSAL

13-33. References

FM 21-10 deals with disposal of wastes under field conditions. TM 5-634 covers collection and disposal of refuse at temporary and permanent installations.

13-34. Definitions

a. Refuse. Garbage, ashes, debris, rubbish, and other domestic and commercial solid waste material. Not included are garbage or other saleable material (sold under contract and delivered to a buyer at point of generation), explosive and incendiary wastes, and contaminated wastes from medical and radiological processes.

(1) *Garbage.* Animal and vegetable waste and containers resulting from the handling, preparation, cooking, and consumption of foods. Edible, or hogfood garbage is the portion of waste food which has been segregated for salvage.

(2) *Ashes.* The residue from burned wood, coal, coke, and other combustible material.

(3) *Debris.* Grass cuttings, tree trimmings, stumps, street sweepings, roofing and construction wastes, and similar waste material resulting from maintenance and repair work.

(4) *Rubbish.* Rubbish consists of a variety of unsalvageable waste material such as metal, glass, crockery, floor sweepings, paper, wrappings, containers, carton, and similar articles not used in preparing or dispensing food. Rubbish is further subdivided into:

(a) Combustible rubbish, which can be burned readily in an incinerator or burning pit.

(b) Noncombustible rubbish, which cannot be burned at ordinary incinerator temperatures (800° F to 1,800° F).

b. Salvage or Saleable Materials. Metal scrap, scrap lumber, crating materials, empty barrels, boxes, textile bags, waste paper, cartons, kitchen waste, and similar materials which are reclaimable or have sale value and are not subject to property accountability. These items are segregated at the pickup station.

c. Pickup Stations. Designated locations within the installation, where refuse and salvage are assembled and stored for collection.

d. Discarding Unit. Any organization or individual that places refuse materials or salvage at the pickup station for collection.

e. Segregation of Materials. The process of sorting refuse, debris, and salvage and placing the sorted materials in designated receptacles at the pickup station.

f. Receptacles or Containers. Cans, drums, bins, or similar receptacles which can be handled easily, and multiple containers which are handled by mechanical truck-mounted hoists. (Indicate the type of contents to be placed in the container by clear markings near, not on, the container.)

g. Refuse Collection. A system of transporting refuse, including nonaccountable salvage, from pickup stations to points of disposal. (Includes hauling garbage to the transfer station when required by the terms of a salvage contract.)

h. Refuse Disposal. The ultimate destruction, burning, burying, or other disposal of refuse.

i. Incineration. The process of burning refuse in an incinerator.

j. Incinerator. A self-inclosed furnace designed for burning combustible refuse.

k. Sanitary Fill. A method of disposing of refuse by compacting it without burning, covering it daily with a layer of compacted earth, and forming it into cells sealed by earth walls and cover.

l. Burning Pit. A three-sided earth revetment above or below grade, or a masonry inclosure, where combustible refuse and debris are burned, the residue either being buried in place or hauled to a regulated dump.

m. Regulated Dump. An area for regulated disposal of incombustible and nonputrescible rubbish, debris, and ashes.

n. Garbage Grinder. A mechanical device which grinds garbage, and flushes the ground particles into a sanitary sewer.

13-35. Methods of Disposal

Refuse is disposed of by burying in a sanitary fill, by incineration, by dumping at sea, or by contract with disposal services.

13-36. Collection

A regular schedule and system of collection is established to fit the particular disposal method. In all cases, stands are installed for cans used for storage of garbage. Military organizations must provide facilities at each messhall for the sanitary handling and storage of garbage until it is collected and for the proper cleansing of cans which are not removed by collectors (TM 5-634). The list of average weights of materials given in table 13-22 is a guide to handling collections.

Table 13-22. Average Weights of Garbage and Refuse Materials

Material	Weights (pounds)	
	Per 32-gallon can	Per cubic foot
Garbage	150 to 225	35 to 53.
Refuse without garbage or ashes	28 to 36	6.5 to 8.5.
Refuse including garbage	39 to 47	9 to 11.
Refuse including both garbage and ashes	56 to 64	13 to 15.
Ashes	141 to 158	33 to 37.

13-37. Disposal by Sanitary Fill

A sanitary fill is an effective method of permanently disposing of all types of waste including dry trash, incombustible rubbish, edible and non-edible garbage, in nearly any proportion. Waste materials are placed in a continuous series of sealed cells, compacted, and thoroughly sealed under 2 feet of soil. The earth covering is obtained from succeeding trenches dug parallel to the original trench. The sanitary-fill method eliminates rat, fly, and mosquito hazards, and smoke and odors resulting from open fires and dumps. Burning materials in sanitary-fill trenches is not permitted because it greatly lessens the effectiveness of the installation and complicates operation. Complete details for the location, construction, and operation of sanitary fills are given in TM 5-634. The depth of the original trench, and the depth of the compacted material, depends on

the size of the installation using the fill and on the amount and kind of waste. Table 13-23 is a guide to be used in determining the depth of the original trench and the depth of the compacted material. Since the second and succeeding trenches are dug only to obtain enough soil for a 2-foot covering over the compacted refuse in the preceding trench, they need not be over 3 feet deep.

13-38. Disposal by Incineration

a. General. Incineration is the disposal of refuse by burning in specially constructed furnaces. Incineration destroys all organic matter, both gaseous and solid, and eliminates all substances likely to undergo bacterial decomposition. Garbage, rubbish, dead animals, and dried sludge from sewage disposal are burned in incinerators. Mixed refuse usually contains enough combustible material to provide the fuel for burning. Additional fuel is used when burning garbage alone.

b. Garbage is shoveled through a charging hole and onto an inclined drying hearth. Flames and hot gases produced by burning material on the grate dry the wet garbage on the drying hearth. As the garbage dries, it falls or is raked down to the burning grates where it burns and forms a solid mass or clinker. This clinker is broken up from time to time and removed to keep it from clogging the burning grate. The ash falls into a pit under the burning grate and is removed when necessary. The ash is disposed of in open dumps.

Table 13-23. Depths, Sanitary Fills

Size of installation	Depth of compacted refuse (feet)	Depth of original trench (feet)
1,000 to 2,000 men	3	2½
2,000 to 4,000 men	3½	3
4,000 to 6,000 men	4	3½
6,000 to 8,000 men	5	4
8,000 to 10,000 men	6	4

c. Construction. One large centrally located incinerator for a base camp or hospital is generally more efficient than a separate small incinerator for each unit. However, when the construction of one central incinerator is not possible, several smaller incinerators are built. Occasionally, because of the limited capacity of incinerators, it is necessary to construct a battery of incinerators at the central location. Construction details for incinerators are given in TM 5-634.

d. Operation. For adequate drying and combustion, the incinerator is heated before attempting to dispose of garbage. A fire is started in the furnace with clean, dry rubbish saved from a previous operation or with wood or coal. After the furnace is hot, the wet refuse is placed on the drying grate at reasonable intervals. Care is taken not to overload the incinerator with wet garbage. As the garbage dries, it is moved toward the burning grate making room on the drying grate for the next charge of wet garbage. Garbage is stored as close to the charging holes as possible for ease in charging. To make the greatest use of the heat, the plant should be operated with as few shutdowns as possible. The charging holes are kept open only when absolutely necessary, because the furnace cools rapidly. Tin cans carried into the furnace with the garbage are removed frequently to prevent decreasing the burning capacity of the grates. Glass, china, box straps, and other metal scrap are removed from the refuse before burning because they impair the efficiency of the incinerator.

e. Collection. Garbage is brought to the incinerators in cans or in truck bodies. The garbage is stockpiled at the charging hole from the cans or trucks. The collection schedule is arranged so lack of garbage does not stop the incinerator. The best collection time is during the forenoon.

13-39. Disposal by Dumping at Sea

Disposal by dumping at sea is not recommended where other methods can be used. It is most practicable for island installations, where the use of sanitary fills is impossible or the construction of incinerators is not feasible. Where islands are close to an inhabited friendly shore, or the body of water is relatively small, disposal by dumping at sea is inadvisable. When dumping in large bodies of water the direction of prevailing winds and currents is considered so as to prevent return of the garbage to shore and to avoid defiling shores elsewhere. The garbage is loaded directly from cans or trucks onto the barge, scow, or other means of transportation, hauled at least 5 miles offshore, and dumped.

13-40. Disposal by Contract

At permanent or semipermanent installations, edible garbage may be sold or given to civilians for use as animal food. The conditions governing such sale or gift are covered in AR 420-47. Before such a contract is awarded, an Army Medi-

cal Service officer should inspect the location where the garbage is to be used to make certain that it will not constitute a hazard to the health or welfare of the troops. The person who receives the waste should provide a truck with a watertight body for the transfer of the garbage at the garbage stand. Emptied garbage cans are to be left at the stand for cleaning by the dining hall personnel. For the sake of maintaining sanitary conditions at the dining halls, personnel collecting the garbage should make the collections at regular intervals and take every precaution to prevent spillage.

13-41. Disposal of Refuse Alone

a. General. Garbage type incinerators and sanitary fills are not practicable for disposing of large amounts of crating, scrap lumber, street sweepings, and incombustible trash. Crating and lumber produce too much heat for ordinary incinerators. The two common methods of disposing of refuse alone are burning pits and regulated dumps.

b. Burning Pits. Masonry or earth pits of varying size and design to meet local requirements are used to burn combustible refuse. However, they are fire hazards and their construction and method of operation must be approved by all fire-protection agencies. The pits are cleaned weekly and all ashes, metal, and other incombustibles are disposed of on regulated dumps. The design of earthen pits depends on the terrain and the quantity of refuse to be burned. A suggested design is a revetment with two horseshoe-shaped cells; each cell is used alternately for dumping and burning. If the pit is large, the ashes are left in the bottom, but periodically they are leveled with a bulldozer or scraper. If the area of the pit is limited, the ashes and incombustibles are removed and placed on a regulated dump.

c. Regulated Dumps. Regulated dumps are used to dispose of incombustible trash. They are built like embankments or highway fills of limited height and area and situated so that they are compacted daily by truck traffic. They are leveled periodically by a bulldozer and kept orderly and free of objectionable contents. If properly operated, regulated dumps are used to reclaim worthless land. Refuse is not dumped over an embankment or the brow of a hill making a high-face dump, because dumps of this kind are difficult to operate under regulated-dump standards.

Section IV. ELECTRIC POWER DISTRIBUTION

13-42. References

TM 5-760 gives necessary details for electrical wiring. Electric power transmission and distribution is covered in TM 5-765. TM 5-766 deals with electric power generation in the field.

13-43. Common Electrical Terms

Ampere (I). Unit of current strength or rate of flow of electricity (1 ampere=1 coulomb/sec).

Capacity. The load for which a machine, apparatus, plant, or system is rated.

Demand Factor. The ratio of the maximum demand to the total connected load.

Efficiency (Eff). The ratio of the useful energy "output" of a machine to its total energy "input".

Horsepower (HP). The time rate of doing work equal to raising 33,000 lb 1 foot in 1 minute. One hp=746 watts.

Kilovolt amperes (KVA). 1000 volt-amperes=kw ÷ Power Factor, or 1000 volts × amperes @ unity power factor.

Kilowatt (KW). 1000 watts or 1.34 horsepower.

Load. The amount of power or kilovolt-amperes (kva) delivered at a given time.

Load Diversity. The ratio of the combined peak demand load and the sum of the peak demands of two or more individual demand loads.

Load Factor. The ratio of the average load over a designated period to the peak load occurring in that period.

Maximum Demand. The greatest demand of a particular type occurring within a specified period.

Ohm (R). Unit of resistance.

Power Factor (PF). Ratio of true to apparent power.

Volt (V,E). Unit of electrical pressure or unit of electromotive force.

Volt Amperes or VA. Unit of apparent power.

Watt (P). Unit of true power = VA × Power Factor.

Watthour (WH). Unit of electrical work employed to indicate the expenditure of electrical power of 1 watt for 1 hour.

13-44. Electrical Symbols

Figure 13-12 gives symbols in conformance with MIL-STD-15-3, dated 30 October 1961.

13-45. Useful Formulas

a. Direct Current.

(1) Electromotive force (voltage) —Ohm's law

$$E = I R$$

(2) Power (watts)

$$P = E I$$

(3) Work or energy (power × time)

$$\text{Work} = P T = E I T$$

b. Alternating Current Formulas.

(1) Apparent power (VA) = E I

(2) True power (P) = I² R

(3) Power factor (PF) = $\frac{P}{VA}$

(4) Power = E I × P F

c. Power Factor Measurements.

(1) Single-phase circuits

$$PF = \frac{P}{E I}$$

Where:

P = wattmeter reading in watts

E = voltmeter reading in volts

I = ammeter reading in amperes

(2) Balanced two-phase, 3-wire circuit

$$PF = \frac{P}{1.414 E I}$$

Where:

P = total power in watts

E = volts between outside wires

I = amperes in outside wire

(3) Balanced three-phase, 3-wire circuit

$$PF = \frac{P}{1.732 E I}$$

Where:

P = total watts

E = volts between wires

I = amperes in a wire

d. Formulas for Design and Analysis. Table 13-24 provides formulas for determining amperes, horsepower, kilowatts, and kilovolt-amperes, and for making conversions from one to another.

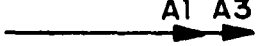
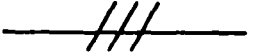
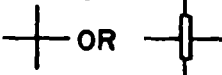
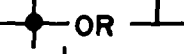
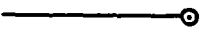
ITEM	SYMBOL
WIRING CONCEALED IN CEILING OR WALL	
WIRING CONCEALED IN FLOOR	
EXPOSED BRANCH CIRCUIT	
BRANCH CIRCUIT HOME RUN TO PANEL BOARD (NO. OF ARROWS EQUALS NO. OF CIRCUITS, DESIGNATION IDENTIFIES DESIGNATION AT PANEL)	
THREE OR MORE WIRES (NO. OF CROSS LINES EQUALS NO. OF CONDUCTORS TWO CONDUCTORS INDICATED IF NOT OTHERWISE NOTED)	
INCOMING SERVICE LINES	
CROSSED CONDUCTORS, NOT CONNECTED	
SPLICE OR SOLDERED CONNECTION	
CABLED CONNECTOR (SOLDERLESS)	
WIRE TURNED UP	
WIRE TURNED DOWN	

Figure 13-12. Standard electrical symbols.

13-46. Foreign Voltages and Frequencies

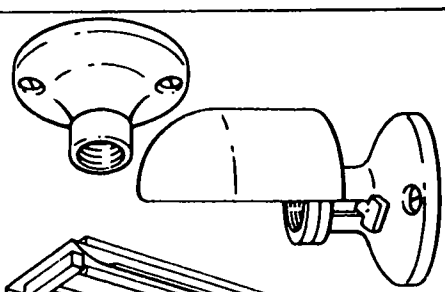
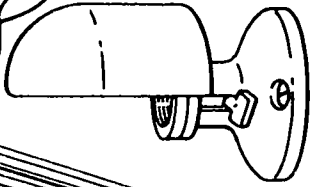
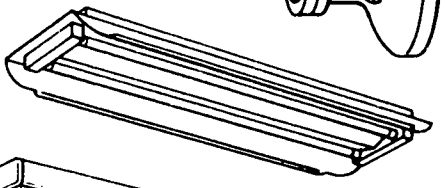
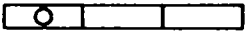
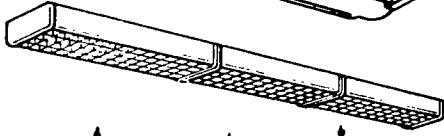
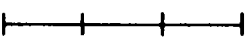
Electric current for lights, motors, and other appliances is usually used at voltages of 115 or 208 volts and distributed at multiples thereof, but there are important exceptions; e.g., the prevailing voltage in Japan is 100. As to the frequencies in alternating current, the lower frequencies permit higher power factors in certain types of motors but cause flicker in incandescent light. The present standard frequency in the United States is 60 cycles, except that 25-cycle current is used for power in some industrial installations. In Europe, a frequency of 50 cycles for illumination and 25- and 42-cycle current for power are standard. Direct-current voltages and alternating-current voltages and frequencies generally used in various countries are given in TM 5-765.

13-47. Single-Phase Systems

Buildings containing single-phase equipment, such as lights, X-ray machine, or single-phase motors are served by two- or three-wire systems. Small loads as required for barracks lighting are served by two-wire systems; large loads require three-wire service.

a. *Two-Wire Systems.* In single-phase systems using two wires, the current in one wire always equals the current in the other, but flows in the opposite direction. Currents in the two wires reverse simultaneously.

b. *Three-Wire Systems.* Single-phase systems of three wires supply two voltages simultaneously. One wire is the neutral and is grounded; the other two are the hot wires. Figure 13-13 shows a typical single-phase three-wire system.

ITEM	SYMBOL	ILLUSTRATION
LIGHTING OUTLETS*- CEILING		
WALL		
FLUORESCENT FIXTURE		
CONTINUOUS ROW FLUORESCENT FIXTURE		
BARE LAMP FLUORESCENT STRIP		

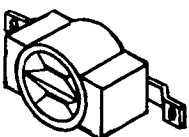
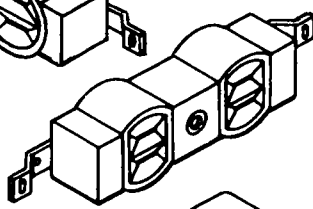
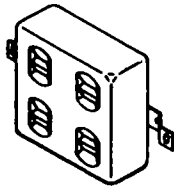
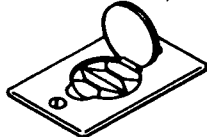
* LETTERS ADDED TO SYMBOLS INDICATE SPECIAL TYPE OR USAGE

J- JUNCTION BOX

R- RECESSED

L- LOW VOLTAGE

X- EXIT LIGHT

RECEPTACLE OUTLETS**- SINGLE OUTLET	 OR 	
DUPLEX OUTLET		
QUADRUPLER OUTLET	 OR 	
SPECIAL PURPOSE OUTLET	 OR 	
20-AMP, 250-VOLT OUTLET		
SINGLE FLOOR OUTLET (BOX AROUND ANY OF ABOVE INDICATES FLOOR OUTLET OF SAME TYPE)	 OR 	

** LETTER G NEXT TO SYMBOL INDICATES GROUNDING TYPE

Figure 13-12. Standard electrical symbols—Continued.

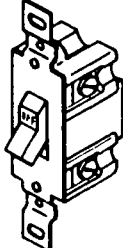
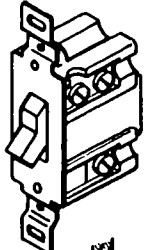
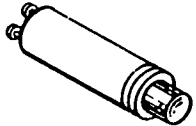
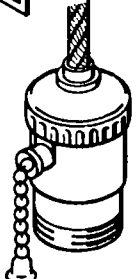
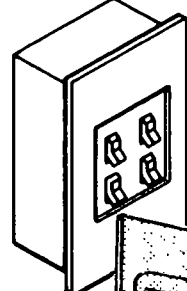
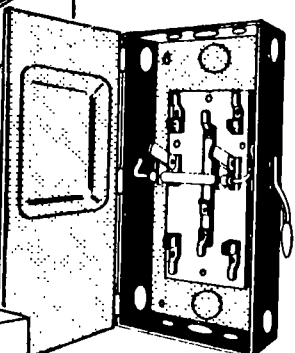
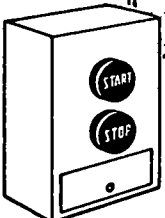
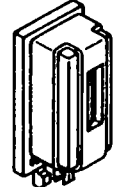
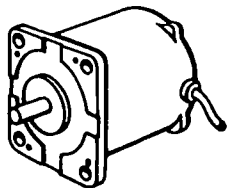
ITEM	SYMBOL	ILLUSTRATION
SWITCHES -		
SINGLE POLE SWITCH	S	
DOUBLE POLE SWITCH	S ₂	
THREE WAY SWITCH	S ₃	
SWITCH AND PILOT LAMP	S _p	
CEILING PULL SWITCH	(S)	
PANEL BOARDS AND RELATED EQUIPMENT		
PANEL BOARD AND CABINET		
SWITCHBOARD, CONTROL STATION OR SUBSTATION		
SERVICE SWITCH OR CIRCUIT BREAKER	 OR  OR 	
EXTERNALLY OPERATED DISCONNECT SWITCH		
MOTOR CONTROLLER	 OR 	
MISCELLANEOUS -		
TELEPHONE		
THERMOSTAT		
MOTOR		

Figure 13-12. Standard electrical symbols—Continued.

Table 13-24. Formulas For Electrical Design and Analysis

To find	Direct current	Alternating current		
		Single phase	Two phase* four wire	Three phase
Amperes when Horsepower is Known	$\frac{hp \times 746}{e \times \% \text{ eff.}}$	$\frac{hp \times 746}{e \times \% \text{ eff.} \times pf}$	$\frac{hp \times 746}{2 \times e \times \% \text{ eff.} \times pf}$	$\frac{hp \times 746}{1.73 \times e \times \% \text{ eff.} \times pf}$
Amperes when Kilowatt is Known	$\frac{kw \times 1000}{e}$	$\frac{kw \times 1000}{e \times pf}$	$\frac{kw \times 1000}{2 \times e \times pf}$	$\frac{kw \times 1000}{1.73 \times e \times pf}$
Amperes when KVA is Known		$\frac{kva \times 1000}{e}$	$\frac{kva \times 1000}{2 \times e}$	$\frac{kva \times 1000}{1.73 \times e}$
Kilowatts	$\frac{i \times e}{1000}$	$\frac{i \times e \times pf}{1000}$	$\frac{i \times e \times 2 \times pf}{1000}$	$\frac{i \times e \times 1.73 \times pf}{1000}$
KVA		$\frac{i \times e}{1000}$	$\frac{i \times e \times 2}{1000}$	$\frac{i \times e \times 1.73}{1000}$
Horsepower Output	$\frac{i \times e \times \% \text{ eff.}}{746}$	$\frac{i \times e \times \% \text{ eff.} \times pf}{746}$	$\frac{i \times e \times 2 \times \% \text{ eff.} \times pf}{746}$	$\frac{i \times e \times 1.73 \times \% \text{ eff.} \times pf}{746}$

i = Amperes; e = Volts; % eff. = percent Efficiency; pf = Power Factor.
kw = Kilowatts; kva = kilo-volt-amperes; hp = horsepower.
*For three-wire, two-phase circuits, the current in the common conductor is 1.41 times that in either of the other two conductors.

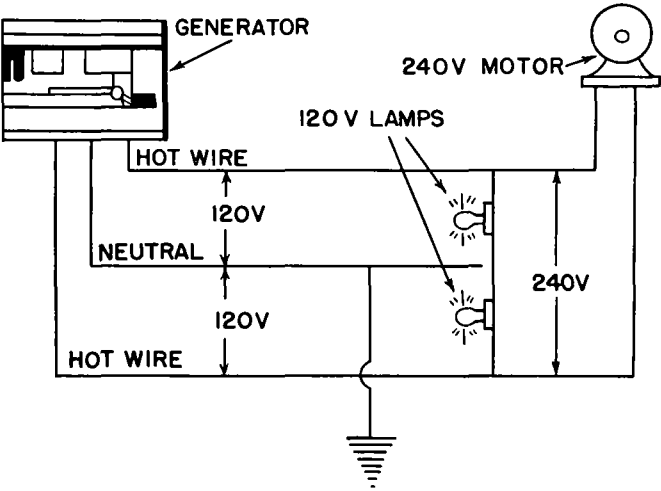


Figure 13-13. Single-phase, three-wire system.

- (1) *Voltages.* The voltage between the two hot wires equals the sum of the voltages between the neutral and each hot wire. Usually, the voltage between the two hot wires is twice the voltage between the neutral and either hot wire.
- (2) *Currents.* The current in the neutral wire equals the difference between the currents in the hot wires, as shown in figure 13-14. Current flows in the neutral wire in the same direction as the current in the hot wire carrying the smaller current. If total watts of load connected

between the neutral and the two hot wires are equal, the loads are balanced. Under this condition, desirable in electric distribution systems, the current in one hot wire equals the current in the other and no current flows in the neutral.

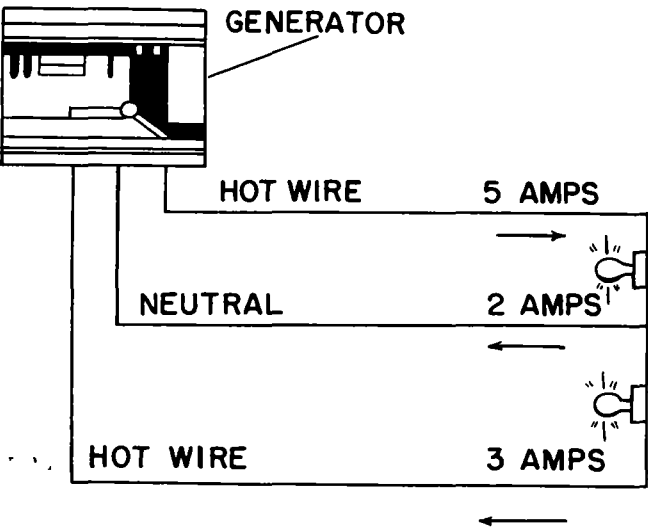


Figure 13-14. Current in neutral wire.

13-48. Two-Phase Systems

The two-phase system has two single-phase currents having a difference in phase of 90°. It is sometimes called "quarter-phase system." The

currents are distributed on the three-wire, four-wire, or five-wire system. This system is not in common usage except in certain localities. Further information may be obtained from the American Electricians' Handbook.

13-49. Three-Phase Systems

A three-phase system is three single-phase systems interlocked so the current in each phase reverses at a different instant than the current in either of the other two phases.

a. Three Phase-Three Wire. Three phase-three wire systems are usually connected in either a *delta* or a *wye* configuration. Each of these connections has definite electrical characteristics. The designations delta and wye are derived from the method of connection.

(1) Delta connection.

(a) The properties of a delta connection may be summarized as follows:

The three windings of the delta connection form a closed loop. The sum of the three equal voltages 120° out of phase with each other is zero. This means that the circulating current in the closed loop is zero. The magnitude of any line current is equal to $\sqrt{3}$ times the magnitude of any phase current

$$I_L = \sqrt{3} \times I_{\text{phase}}$$

(b) The three phase three-wire delta configuration is used primarily for wiring three phase motors because the circuit must be balanced. It offers economic application where power load is large compared with lighting load.

(2) Wye connection.

(a) The properties of the wye connection may be summarized as follows: The three windings of the wye connection do not form a closed loop. The magnitude of the voltage between any two lines equals the magnitude of any phase voltage times $\sqrt{3}$, or

$$E_L = \sqrt{3} \times E_{\text{phase}}$$

The current in any winding equals the current in the line.

(b) Three phase-three wire wye configuration is not used commonly as the circuits must be perfectly balanced for maximum efficiency. Normally, a fourth wire (neutral) is added to make the circuit three phase-four wire.

b. Three Phase-Four Wire. Three phase systems using three-phase wires and one neutral wire provide a flexible means of obtaining both lighting and power from the same circuit and are commonly used. Three-phase systems are

better suited than single-phase systems to heavy loads, especially large motors. Figure 13-15 shows a typical three-phase four-wire system.

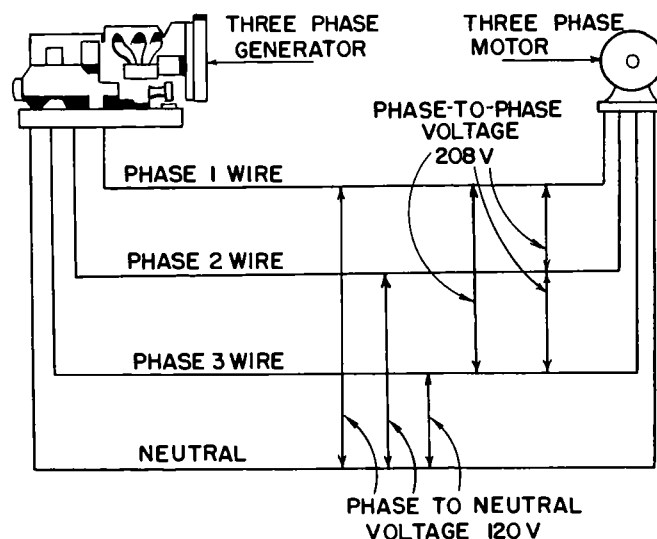


Figure 13-15. Three-phase four-wire system.

(1) *Voltages.* Two voltages are available simultaneously from a three-phase four-wire system, the phase-to-phase voltage.

(a) *Phase-to-neutral* voltage is the voltage between any phase wire and the neutral.

(b) *Phase-to-phase* voltage is the voltage between any two phase wires. Phase-to-phase voltage equals 1.73 multiplied by the phase-to-neutral voltage.

(2) *Currents.* As in the single-phase system, the loads between the neutral and each phase wire are balanced to reduce current in the neutral to a minimum. A perfectly balanced three-phase system carries equal currents in the phase wires and no current in the neutral.

13-50. Comparison of Systems

Systems are identified by the number of phases and wires and the voltages between wires. For example, the single-phase three-wire system, the voltage is 120 volts from hot wire to neutral, and 240 volts between hot wires. This notation is abbreviated 1Ø3w 120/240v. The three-phase four-wire system shown in figure 13-15 is abbreviated 3Ø4w 127/220v.

13-51. Electric-Power Requirements

a. Procedure. Predetermine the maximum demand in kilowatts and the average consumption of energy in kilowatt hours when selecting a

suitable power supply, specifying the proper equipment, and computing the cost of electricity.

b. Maximum Demand. The most accurate means of estimating the demand is to determine the connected load and apply suitable diversity factors. These factors are based on experience with projects similar in character and size to that under consideration. A breakdown of large projects and a classification of the types of service required may be helpful in estimating the total maximum demand and in applying the data obtained from other projects containing facilities of similar nature but not necessarily of the same size and composition. In general, the maximum 30-minute demand for the entire electrical system at posts, camps, and airfields will be approximately 40 percent of the total connected load, and at storage depots will be approximately 200 kilowatts per million square feet of warehouse area. For industrial plants, the maximum demand should be determined from data furnished by using service. On a per capita and bed basis, the following demands will be sufficiently accurate for preliminary estimating purposes:

Army camps	0.4	kw per capita
Air Force tactical bases	0.4	kw per capita
Air Force strategic bases	0.4	kw per capita
Research and development bases	1.6	kw per capita
Technical schools	0.75	kw per capita
Repair schools	1.85	kw per capita
Hospitals	1.6	kw per bed

In applying the above figures to a specific project, special application must be considered. Where other than normal loads are to be supplied, allowances must be made for the demands that will be imposed by these loads.

c. Consumption. The average monthly consumption should be computed by multiplying the maximum demand by a suitable load factor and by the number of hours the facility will be in operation during the month. The load factor will usually be between 30 and 45 percent at posts, camps, airfields, and storage depots. For instance, at an Army post having a total connected load of 8,000 kilowatts, the estimated maximum demand would be $8,000 \times 0.40 = 3,200$ kilowatts. Using a load factor of 45 percent, the estimated average monthly consumption would be $3,200 \times 0.45 \times 720 = 1,036,800$ kilowatt-hours. Similarly, using the per capita basis, at an Army post having an authorized strength of 8,000 men, the estimated maximum demand would be $8,000 \times 0.4 = 3,200$ kilo-

watts. Again using a load factor of 45 percent, the estimated average monthly consumption would be $3,200 \times 0.45 \times 720 = 1,036,800$ kilowatt-hours.

13-52. Transformers

a. General. A transformer receives electrical energy from one circuit and transfers it to another circuit by electromagnetic action. The circuit from which energy is received is called the primary; the receiving circuit is the secondary. Usually the primary and secondary circuits are at different voltages. An elementary transformer consists of a primary and a secondary coil surrounding an iron core. Alternating current in the primary coil produces an alternating magnetic field in the iron core. A voltage is induced in the secondary coil by the alternating field.

b. Substation Transformers. Substation transformers should be of the outdoor type and of applicable self-cooled rating selected from standard transformer kva ratings.

(1) *Standard kva ratings in single-phase transformers* are: 5, 10, 15, 25, 37.5, 50, 75, 100, 167, 250, 333, 500, 833, 1,250, 1,667, 2,500, 3,333, 5,000, 6,667, 8,333, 12,500, 16,667, 20,000, 25,000, and 33,333.

(2) *Standard kva ratings in three-phase transformers* are: 15, 30, 45, 75, 112½, 150, 225, 300, 500, 750, 1,000, 1,500, 2,000, 2,500, 3,750, 5,000, 7,500, 10,000, 12,000, 15,000, 20,000, 25,000, 30,000, 37,500, and 50,000.

13-53. Generators

a. Definitions.

(1) *Type.*

(a) *Type I—Tactical.* Generator sets designed for high mobility and minimum weight. Maximum weights for Tactical engine generator sets are listed in table 13-25.

(b) *Type II—Prime.* Generator sets designed for long life with secondary considerations for mobility and weight. (Generator sets exceeding the maximum weights for table 13-25, Tactical, will be classified Type II, Prime.)

(2) *Class.*

(a) *Class 1—Precise.* Generator sets designed to provide a high voltage and frequency control.

(b) *Class 2—Utility.* Generator sets designed to provide power for general purpose applications where "precise power" is not required.

(3) *Mode.*

(a) *Mode I.* Generator sets capable of operating at either 50 to 60 Hz.

(b) *Mode II.* Generator sets operating at 400 Hz.

(c) *Mode III.* Generator sets operating only at 60 Hz.

(d) *Mode IV.* Generator sets providing dc output.

(4) *Standard voltage connections for engine generator sets.* The respective standard voltage connections for generator sets are listed in table 13-26. Where more than one standard voltage connection is shown for a DoD standard kw rating, suitable means are provided to enable reconnecting the generator windings to give all required output voltages at the load terminals of the generator set.

b. General Requirements.

(1) *Environmental conditions.* Normal electrical performance characteristic parameters are applicable throughout the temperature ranges of minus 65° F. (53.9° C.) to plus 125° F. (51.7° C.) to sea level and to an altitude of 5,000 feet (632.4 mm Hg) at 107° F. (41.7° C.), except for generator sets rated 5000 KW and above. For generator sets rated 500 KW and above normal electrical performance characteristic parameters are applicable throughout the temperature range of minus 25° F. (31.7° C.) to plus 125° F.

(51.7° C.) at sea level and to an altitude of 1,500 feet (719.8 mm Hg) at 90° F (32.2° C).

(2) *Power rating.* Engine generator sets with dual frequency capability (50/60 Hz) have KW ratings at 50 Hz which are 5/6 of the 60 Hz KW ratings.

(3) *Standard connections.* Standard connections are shown in table 13-26.

Table 13-25. Maximum Dry Weights for Tactical Generator Sets

KW rating	Type of engine	Maximum dry weight ¹ (pounds)
0.5	Spark Ignition ² (SI)	80
1.5	Spark Ignition	140
3.0	Spark Ignition	300
3.0	Compression Ignition ³ (CI)	425
5.0	Spark Ignition	525
5.0	Compression Ignition	900
10	Spark Ignition	900
10	Compression Ignition	1,100
15	Compression Ignition	2,800
30	Compression Ignition	3,500
60	Compression Ignition	5,000
100	Compression Ignition	7,000
150	Compression Ignition	9,000
200	Compression Ignition	10,500
300	Compression Ignition	14,000
500	Compression Ignition	30,000

¹ Maximum dry weight is the weight of the generator set less fuel, coolant, lubricant, electrolyte and optional equipment. Optional equipment weights are shown in MIL-STD-633.

² Gasoline.

³ Diesel.

Table 13-26. Standard Voltage Connections for 60 Hz, 50/60 Hz, 400 Hz and dc Engine Generator Sets

DoD standard KW rating	Voltage connections (ac)						
	Single phase				Three phase		
	120 volt, 2 wire	240 volt, 2 wire	120/240 volt, 3 wire	120/208 volt, 4 wire	240/416 volt, 4 wire	2400/4160 volt, 4 wire	2400 volt, 3 wire
0.5, 1.5	X	X					
3, 5	X	X		X			
10	X		X	X			
15, 30, 60, 100, 150, 200, 300				X	X		
500, 750, 1000, 1500, 2000						X	X

Notes. 1. The DoD standard family also includes 28 volt dc engine generator sets rated 0.5 KW, 1.5 KW, and 3 KW.

2. Engine generator sets which operate at 50 Hz are capable of being adjusted to and operate at 190/380 volts for the 240/416 volt connection and 1900/3800 volts for the 2400/4160 volt connection.

13-54. Power Systems

a. Load Estimation.

(1) *Connected load.* Load estimation covers both the size and location of the items making up the connected load. The structures to be served are identified and marked on an accurately scaled map of the area. The connected load for each structure is then established and tabulated. The connected load is the sum of the electric-current

requirement of each motor light, and other electrically operated devices, expressed in kilovolt-amperes (kva). One thousand watts in incandescent lamps, or 1 horsepower of motor or power load is taken as 1 kva in estimating the connected load. The connected light and power loads for various standard buildings are given in TM 5-302. Connected loads for other structures may be estimated by comparing floor areas.

(2) *Demand load.* The connected load is converted to demand load by applying a demand factor which is based on experience. The term load or demand, used alone, means demand load, in kva required to serve a given connected load. It is less than the connected load because all of the lights or other electric devices are not in use simultaneously. The demand factor is the ratio of the maximum demand of a system, or part of the system under consideration to the connected load. Demand factors for military structures are shown in table 13-27. Using these, the demand for each structure is computed and tabulated.

(3) *Horsepower limits.* Horsepower limits of electric motors by systems and voltages are shown in table 13-28.

Table 13-27. Demand Factors, Military Structures

Structure	Demand factor
Housing	0.9
Aircraft maintenance, facilities	.7
Operation facilities	.8
Administrative facilities	.8
Shops	.7
Warehouses	.5
Medical facilities	.8
Theaters	.5
NAV aids	.7
Laundry, ice plants, and bakeries	1.0
All others	.9

Table 13-28. Horsepower Limits

System	Voltages	Minimum horsepower	Maximum horsepower
Alternating current, single phase.	110-115-120	None	1½
	220-230-240	None	10
	440-550	5	10
Alternating current, two and three-phase.	110-115-120	None	15
	220-230-240	None	200
	440-550	None	500
	2200	40	None
	4000	75	None
Direct current ----	6600	400	None
	115	None	30
	230	None	200
	550-600	½	None

(4) *Standard horsepower.* Standard horsepower ratings of motors are: $\frac{1}{20}$, $\frac{1}{12}$, $\frac{1}{8}$, $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 2, 3, 5, $7\frac{1}{2}$, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100, 900, 1,000, 1,250, 1,500, 1,750, 2,000, 2,250, 2,500, 3,000, 3,500, 4,000, 4,500, and 5,000.

b. Generator Location and Capacity.

(1) *Location.* To reduce wire requirements, generators are located preferably near points of large demand such as laundries, machine shops, bakeries, ice plants, and X-ray equip-

ment. Generator locations are selected tentatively by map study of the plotted demands. The size of the area served by each low-voltage generator or transformer depends upon the type and location of the demands. In general, small demands. In general, small demands such as barracks lighting are served efficiently at distances up to 1,500 feet, moderate demands such as mess structures, up to 1,000 feet. Generators are located on firm ground and along existing roads. Concrete foundations are justified for semipermanent installations of 30-kilowatt or large generators.

(2) *Capacity.* Generator capacity is based on the sum of the demands served but is less than the sum because the peak demands are not simultaneous. The sum of the individual demands, in kva, is multiplied by a generator factor to determine the required generator capacity in kilowatts. The factor allows both for the power factor (pf) of the generator and for the noncoincidence of demands. Generator factors for theater-of operations construction are given, in table 13-29. The diversity factor is discussed in TM 5-765.

Table 13-29. Generator Factors, Theater-of-Operations Construction

Type of load	Generator factor
Lighting	1.00
Predominantly lighting with some motors	.95
Lighting with ranges and water heaters	.95
Lighting and motors about equal	.90
Predominantly motors with some lighting	.85
Motors	.80

(3) *Number of generators.* Table 13-26 lists the generators currently available in the Army. Whether the distribution system is being planned around available generators or the generator requirements are being determined for a given distribution system, enough excess generator capacity should be provided to supply the maximum demand with the largest generator out of service. In small systems, generators are preferably of the same size and type, for interchangeability and to reduce the requirements for spare parts. In larger systems, generators of different sizes are justified to permit more efficient operation. For example, if a 150-kilowatt lighting demand is served by one 60-kilowatt, one 100-kilowatt, and one 150-kilowatt generator, any one generator can be out of service at any time; and the 60-kilowatt generator will probably supply the entire demand in daytime hours.

(4) *Interconnection.* Generator locations

in hospital areas and refrigeration warehouse areas are usually interconnected to insure uninterrupted service. Interconnections require additional copper and are not justified except in hospital and refrigeration areas. If the supply of generators does not permit either interconnection or standby capacity as described in (3) above, the operating rooms and one or two lights per ward are wired on a special circuit to a small emergency generator.

c. Transformer Location and Capacity. Transformers are required wherever the utilization voltage differs from the transmission or distribution voltage. Their location is influenced by the same factors which affect generator locations (b (1) above). The proper transformer capacity in kva is the same as the full demand in kva (without reduction as in the case of generators). In selecting and locating transformers for lighting loads in military housing areas, a frequently used combination is 10 kva transformer distributing through three No. 6 conductors carrying single-phase 120/240 volt current.

d. Line Location. Normally electric distribution systems are of the radial type; lines radiate

from generators or substations toward loads, branching and rebranching until all areas are served. The alternative is the ring type system in which the main distribution line forms a closed loop. The ring type normally distributes with less voltage drop but requires more time and material to construct. Lines are normally overhead. Lines carrying voltages above 240 are supported on poles (TM 5-680C); those carrying 120-240 volts are supported on poles or on masts or insulators attached to buildings.

13-55. Selecting Wire Sizes

a. Requirements. Electric conductors must be large enough to carry the current without heating unduly and without excessive voltage drop. Except for very short lines, the latter requirement is usually the controlling one.

b. Current Carrying Capacity. Table 13-30 describes types of conductor insulation and gives temperature ratings for their use. Tables 13-31 through 13-35 give allowable current carrying capacity for various sizes of copper and aluminum conductors, and correction factors for variations in temperature.

Table 13-30. Conductor Insulation

Trade name	Type letter	Temperature rating	Application provisions
Rubber-Covered Fixture Wire	*RF-1	60°C 140°F	Fixture wiring. Limited to 300 V.
Solid or 7-Strand	*RF-2	60°C 140°C	Fixture wiring.
Rubber-Covered Fixture Wire	*FF-1	60°C 140°F	Fixture wiring. Limited to 300 V.
Flexible Stranding	*FF-2	60°C 140°F	Fixture wiring.
Heat-Resistant Rubber-Covered Fixture Wire.	*RFH-1	75°C 167°F	Fixture wiring. Limited to 300 V.
Solid or 7-Strand	*RFH-2	75°C 167°F	Fixture wiring.
Heat-Resistant Rubber-Covered Fixture Wire.	*FFH-1	75°C 167°F	Fixture wiring. Limited to 300 V.
Flexible Stranding	*FFH-2	75°C 167°F	Fixture wiring.
Thermoplastic-Covered Fixture Wire—Solid or Stranded.	*TF	60°C 140°F	Fixture wiring.
Thermoplastic-Covered Fixture Wire—Flexible Stranding.	*TFF	60°C 140°F	Fixture wiring.

See note below table.

Table 13-30. Conductor Insulation—Continued

Trade name	Type letter	Temperature rating	Application provisions
Heat Resistant Thermoplastic-Covered Fixture Wire— Solid or Stranded.	*TFN	90°C	Fixture wiring.
Heat Resistant, Thermoplastic-Covered Fixture Wire— Flexible Stranding.	*TFFN	90°C	Fixture wiring.
Cotton-Covered, Heat-Resistant, Fixture Wire.	*CF	90°C 194°F	Fixture wiring. Limited to 300 V.
Asbestos-Covered Heat-Resistant Fixture Wire.	*AF	150°C 302°F	Fixture wiring. Limited to 300 V. and Indoor Dry Location.
Flourinated Ethylene Propylene Fixture Wire, Solid or 7-Strand.	*PF *PGF	150°C 302°F	Fixture wiring.
Fluorinated Ethylene Propylene Fixture Wire	*PFF *PGFF	150°C 302°F	Fixture wiring.
Silicone Rubber Insulated Fixture Wire.	*SF-1	200°C 392°F	Fixture wiring. Limited to 300 V.
Solid or 7 Strand	*SF-2	200°C 392°F	Fixture wiring.
Silicone Rubber Insulated Fixture Wire.	*SFF-1	150°C 302°F	Fixture wiring. Limited to 300 V.
Flexible Stranding	*SFF-2	150°C 302°F	Fixture wiring.
Heat-Resistant Rubber	RH	75°C 167°F	Dry locations.
Heat-Resistant Rubber	RHH	90°C 194°F	Dry locations.
Moisture and Heat Resistant Rubber.	RHW	75°C 167°F	Dry and wet locations. For over 2000 volts, insulation shall be ozone-resistant.
Heat-Resistant Latex Rubber	RUH	75°C	Dry locations.
Moisture Resistant Latex Rubber.	RUW	60°C 140°F	Dry and wet locations.
Thermoplastic	T	60°C 140°F	Dry locations.
Moisture-Resistant Thermoplastic.	TW	60°C 140°F	Dry and wet locations.
Heat-Resistant Thermoplastic	THHN	90°C 194°F	Dry locations.
Moisture and Heat-Resistant Thermoplastic.	THW	75°C 167°F	Dry and wet locations.
Moisture and Heat-Resistant Thermoplastic.	THWN	75°C 167°F	Dry and wet locations.

See note below table.

Table 13-30. Conductor Insulation—Continued

Trade name	Type letter	Temperature rating	Application provisions
Moisture and Heat-Resistant Cross-Linked Thermosetting Polyethylene.	XHHW	90°C 194°F 75°C 167°F	Dry locations. Wet locations.
Moisture-, Heat-, and Oil-Resistant Thermoplastic.	MTW	60°C 140°F 90°C 194°F	Wet locations. Machine tool wiring. Dry locations. Machine tool wiring.
Moisture-, Heat-, and Oil-Resistant Thermoplastic.	THW-MTW	75°C 167°F 90°C 194°F	Dry and wet locations. Special applications within electric discharge lighting equipment. Limited to 1000 open-circuit volts or less. (Size 14-8 only).
Thermoplastic and Asbestos	TA	90°C 194°F	Switchboard wiring only.
Thermoplastic and Fibrous Outer Braid.	TBS	90°C 194°F	Switchboard wiring only.
Synthetic Heat-Resistant	SIS	90°C 194°F	Switchboard wiring only.
Mineral Insulation (Metal Sheathed).	MI	85°C 185°F 250°C 482°F	Dry and wet locations with Type O Termination fittings. For special applications.
Silicone-Asbestos	SA	90°C 194°F 125°C 257°F	Dry locations. For special application.
Fluorinated Ethylene Propylene.	FEP or FEPB	90°C 194°F 200°C 392°F	Dry locations. Dry locations—special applications.
Varnished Cambric	V	85°C 185°F	Dry locations only. Smaller than No. 6 by special permission.
Asbestos and Varnished Cambric.	AVA	110°C 230°F	Dry locations only.
Asbestos and Varnished Cambric.	AVL	110°C 230°F	Dry and wet locations.
Asbestos and Varnished Cambric.	AVB	90°C 194°F	Dry locations only.
Asbestos	A	200°C 392°F	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus. Limited to 300 V.
Asbestos	AA	200°C 392°F	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus or as open wiring. Limited to 300 V.
Asbestos	AI	125°C 257°F	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus. Limited to 300 V.
Asbestos	AIA	125°C 257°F	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus or as open wiring.
Paper		85°C 185°F	For underground service conductors, or by special permission.

*Fixture wires are not intended for installation as branch circuit conductors nor for the connection of portable or stationary appliances.

*Table 13-31. Allowable Current-Carrying Capacity of Copper Conductors—
Not More than Three Conductors in Raceway or Cable*

Size	Temperature Rating of Conductor *					
AWG MCM	60°C (140°F)	75°C (167°F)	85°-90°C (185°F)	110°C (230°F)	125°C (257°F)	200°C (392°F)
14	15	15	25†	30	30	30
12	20	20	20†	35	40	40
10	30	30	40†	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	---
300	240	285	300	345	380	---
350	260	310	325	390	420	---
400	280	335	360	420	450	---
500	320	380	405	470	500	---
600	355	420	455	525	545	---
700	385	460	490	560	600	---
750	400	475	500	580	620	---
800	410	490	515	600	640	---
900	435	520	555	---	---	---
1000	455	545	585	680	730	---
1250	495	590	645	---	---	---
1500	520	625	700	785	---	---
1750	545	650	735	---	---	---
2000	560	665	775	840	---	---

Correction factors, room temps. over 30°C, 86°M

C F						
40 104	.82	.88	.90	.94	.95	---
45 113	.71	.82	.85	.90	.92	---
50 122	.58	.75	.80	.87	.89	---
55 131	.41	.67	.74	.83	.86	---
60 140	---	.58	.67	.79	.83	.91
70 158	---	.35	.52	.71	.76	.87
75 167	---	---	.43	.66	.72	.86
80 176	---	---	.30	.61	.69	.84
90 194	---	---	---	.50	.61	.80
100 212	---	---	---	---	.51	.77
120 248	---	---	---	---	---	.69
140 284	---	---	---	---	---	.50

These current capacities relate only to conductors described in table 13-30.

† The current capacities for types FEP, FEPB, PHH and THHN conductors for sizes AWG 14, 12 and 10 shall be the same as designated for 75°C conductors in this table.

* See table 13-30 for temperature rating of conductor.

*Table 13-32. Allowable Current-Carrying Capacity of Copper
Conductors in Free Air*

Size	Temperature Rating of Conductor*						
AWG MCM	60°C (140°F)	75°C (167°F)	85°-90°C (185°F)	110°C (230°F)	125°C (257°F)	200°C (392°F)	Bare & Covered Conductor
14	20	20	30†	40	40	45	30
12	25	25	40†	50	50	55	40
10	40	40	55†	65	70	75	55
8	55	65	70	85	90	100	70
6	80	95	100	120	125	135	100
4	105	125	135	160	170	180	130
3	120	145	155	180	195	210	150
2	140	170	180	210	225	240	175
1	165	195	210	245	265	280	205
0	195	230	245	285	305	325	235
00	225	265	285	330	355	370	275
000	260	310	330	385	410	430	320
0000	300	360	385	445	475	510	370
250	340	405	425	495	530	---	410
300	375	445	480	555	590	---	460
350	420	505	530	610	655	---	510
400	455	545	575	665	710	---	555
500	515	620	660	765	815	---	630
600	575	690	740	855	910	---	710
700	630	755	815	940	1005	---	780
750	655	785	845	980	1045	---	810
800	680	815	880	1020	1085	---	845
900	730	870	940	----	----	---	905
1000	780	935	1000	1165	1240	---	965
1250	890	1065	1130	----	----	---	----
1500	980	1175	1260	1450	----	---	1215
1750	1070	1280	1370	----	----	---	----
2000	1155	1385	1470	1715	----	---	1405

Correction factors, room temps. over 30°C, 86°F

C F							
40 104	.82	.88	.90	.94	.95	---	----
45 113	.71	.82	.85	.90	.92	---	----
50 122	.58	.75	.80	.87	.89	---	----
55 131	.41	.67	.74	.83	.86	---	----
60 140	---	.58	.67	.79	.83	.91	----
70 158	---	.35	.52	.71	.76	.87	----
75 167	---	---	.43	.66	.72	.86	----
80 176	---	---	.30	.61	.69	.84	----
90 194	---	---	---	.50	.61	.80	----
100 212	---	---	---	---	.51	.77	----
120 248	---	---	---	---	---	.69	----
140 284	---	---	---	---	---	.50	----

These current capacities relate only to conductors described in table 13-30.

† The current capacities for types FEP, FEPB, RHH and THHN conductors for sizes AWG 14, 12 and 10 shall be the same as designated for 75°C conductors in this table.

* See table 13-30 for temperature rating of conductor.

*Table 13-33. Allowable Current-Carrying Capacity of Aluminum Conductors—
Not More than Three Conductors in Raceway or Cable*

Size	Temperature Rating of Conductor **					
AWG MCM	60°C (140°F)	75°C (167°F)	85°-90°C (185°F)	110°C (230°F)	125°C (257°F)	200°C (392°F)
12	15	15	25†	25	30	30
10	25	25	30†	35	40	45
8	30	40	40†	45	50	55
6	40	50	55	60	65	75
4	55	65	70	80	90	95
3	65	75	80	95	100	115
*2	75	90	95	105	115	130
*1	85	100	110	125	135	150
*0	100	120	125	150	160	180
*00	115	135	145	170	180	200
*000	130	155	165	195	210	225
*0000	155	180	185	215	245	270
250	170	205	215	250	270	---
300	190	230	240	275	305	---
350	210	250	260	310	335	---
400	225	270	290	335	360	---
500	260	310	330	380	405	---
600	285	340	370	425	440	---
700	310	375	395	455	485	---
750	320	385	405	470	500	---
800	330	395	415	485	520	---
900	355	425	455	---	---	---
1000	375	445	480	560	600	---
1250	405	485	530	---	---	---
1500	435	520	580	650	---	---
1750	455	545	615	---	---	---
2000	470	560	650	705	---	---

Correction factors, room temps. over 30°C, 86°F

C F						
40 104	.82	.88	.90	.94	.95	---
45 113	.71	.82	.85	.90	.92	---
50 122	.58	.75	.80	.87	.89	---
55 131	.41	.67	.74	.83	.86	---
60 140	---	.58	.67	.79	.83	.91
70 158	---	.35	.52	.71	.76	.87
75 167	---	---	.43	.66	.72	.86
80 176	---	---	.30	.61	.69	.84
90 194	---	---	---	.50	.61	.80
100 212	---	---	---	---	.51	.77
120 248	---	---	---	---	---	.69
140 284	---	---	---	---	---	.50

These current capacities relate only to conductors described in table 13-30.

*For three wire, single phase service and sub-service circuits, the allowable current capacity of RH, RH-RW, RHH, RHW, and THW aluminum conductors shall be for sizes #2-100 Amp., #1-110 Amp., #1/0-125 Amp., #2/0-150 Amp., #3/0-170 Amp and #4/0-200 Amp.

†The current capacities for types RHH and THHN conductors for sizes AWG 12, 10 and 8 shall be the same as designated for 75°C conductors in this table.

**See table 13-30 for temperature rating of conductor.

Table 13-34. Allowable Current-Carrying Capacity of Aluminum Conductors in Free Air

Size	Temperature Rating of Conductor*						Bare & Covered Conductor
AWG MCM	60°C (140°F)	75°C (167°F)	85°-90°C (185°F)	110°C (230°F)	125°C (257°F)	200°C (392°F)	
12	20	20	30†	40	40	45	30
10	30	30	45†	50	55	60	45
8	45	55	55†	65	70	80	55
6	60	75	80	95	100	105	80
4	80	100	105	125	135	140	100
3	95	115	120	140	150	165	115
2	110	135	140	165	175	185	135
1	130	155	165	190	205	220	160
0	150	180	190	220	240	255	185
00	175	210	220	255	275	290	215
000	200	240	255	300	320	335	250
0000	230	280	300	345	370	400	290
250	265	315	330	385	415	---	320
300	290	350	375	435	460	---	360
350	330	395	415	475	510	---	400
400	355	425	450	520	555	---	435
500	405	485	515	595	635	---	490
600	455	545	585	675	720	---	560
700	500	595	645	745	795	---	615
750	515	620	670	775	825	---	640
800	535	645	695	805	855	---	670
900	580	700	750	---	---	---	725
1000	625	750	800	930	990	---	770
1250	710	855	905	---	---	---	---
1500	795	950	1020	1175	---	---	985
1750	875	1050	1125	---	---	---	---
2000	960	1150	1220	1425	---	---	1165

Correction factors, room temps. over 30°C, 86°F

C F							
40 104	.82	.88	.90	.94	.95	---	---
45 113	.71	.82	.85	.90	.92	---	---
50 122	.58	.75	.80	.87	.89	---	---
55 131	.41	.67	.74	.83	.86	---	---
60 140	---	.58	.67	.79	.83	.91	---
70 158	---	.35	.52	.71	.76	.87	---
75 167	---	---	.43	.66	.72	.86	---
80 176	---	---	.30	.61	.69	.84	---
90 194	---	---	---	.50	.61	.80	---
100 212	---	---	---	---	.51	.77	---
130 248	---	---	---	---	---	.69	---
140 284	---	---	---	---	---	.50	---

These current capacities relate only to conductors described in table 13-30.

†The current capacities for types RHH and THHN conductors for sizes AWG 12, 10, and 8 shall be the same as designated for 75°C conductors in this table.

*See table 13-30 for temperature rating of conductor.

Table 13-35. *Reduction of Current-Carrying Capacity For More Than Three Conductors in Raceway or Cable*

Number of conductors	Percent reduction of tables 13-31 and 13-33
4 to 6	80
7 to 24	70
25 to 42	60
43 and above	50

c. Voltage Drop.

(1) *Allowable drop.* The voltage drop is the total loss of voltage from the generator (or transformer or substation at which voltage is controlled) to the lights or motors. Part of the drop occurs in the distribution system (mains), part in the wires from the service entrance to the panel board (feeders), and part in the wires from the panel board to the outlet (branches).

Electric wiring and distribution systems are planned for a total drop not in excess of 8 percent for lighting and 5 percent for power.

(2) *Drop in distribution lines.* Voltage drop is difficult to compute but is obtained accurately enough for wiring layouts from the charts in figures 13-16 through 13-20. A separate chart is given for each voltage and type of circuit normally used in military systems. The upper scales of load and percent drop are used for heavier loads; the lower scales for light loads. Although drawn for 60-cycle current at various wire spacings, the charts may be used safely for 50-cycle current at the same spacings. In addition to the line voltage drop, a drop of 1 volt is added for each standard stepdown transformer which forms a part of any line between an initial known voltage and a final load.

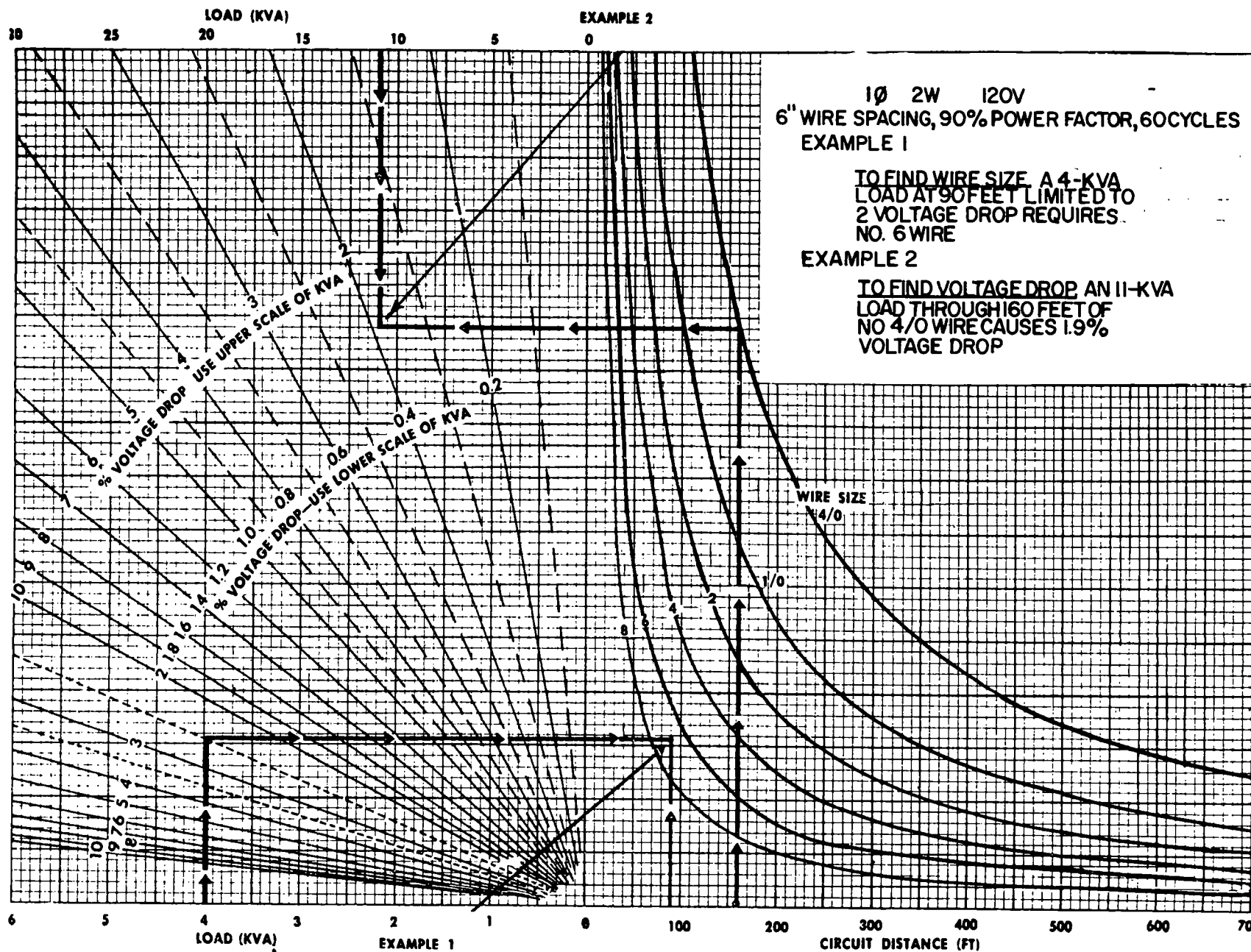
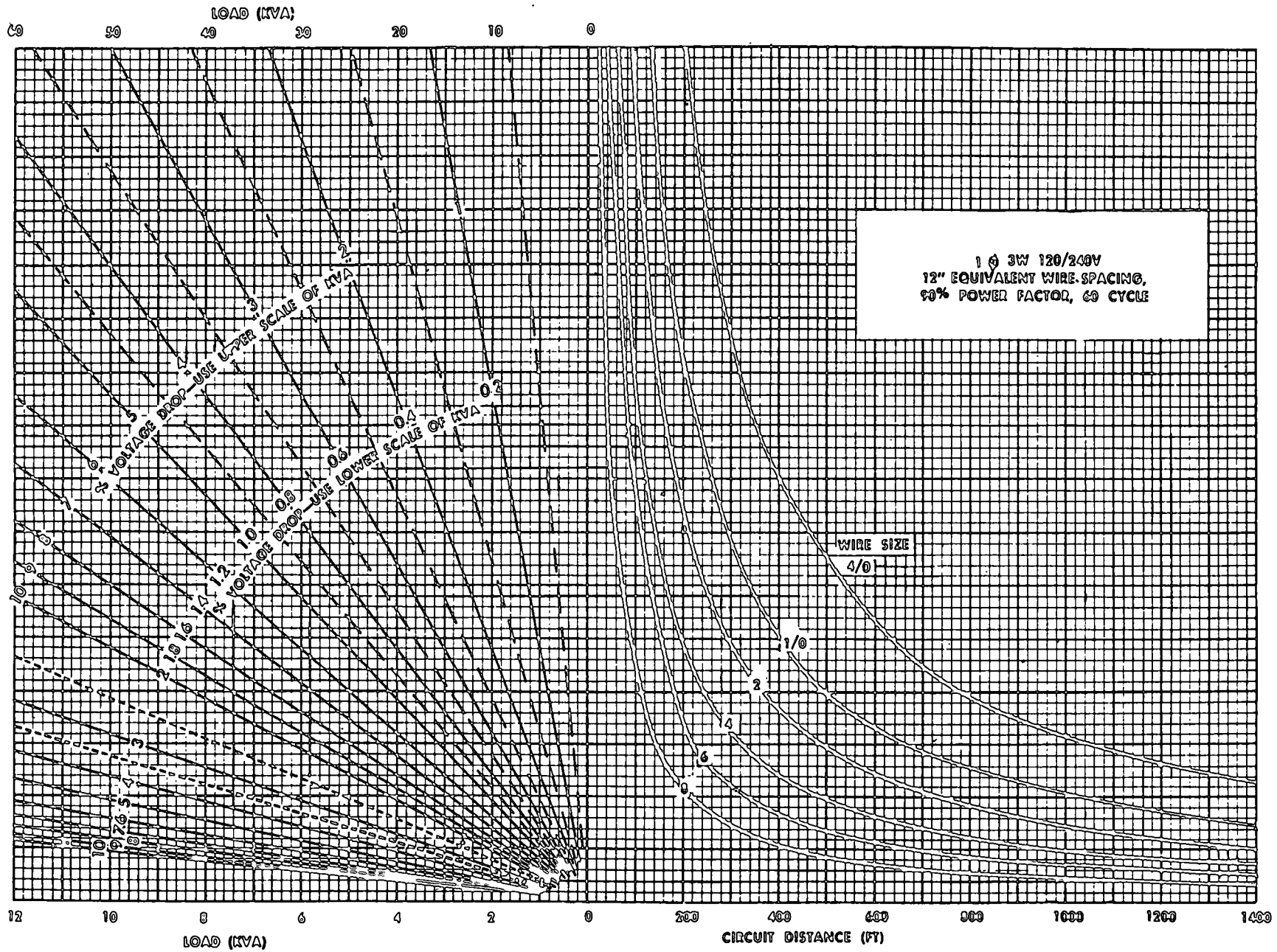
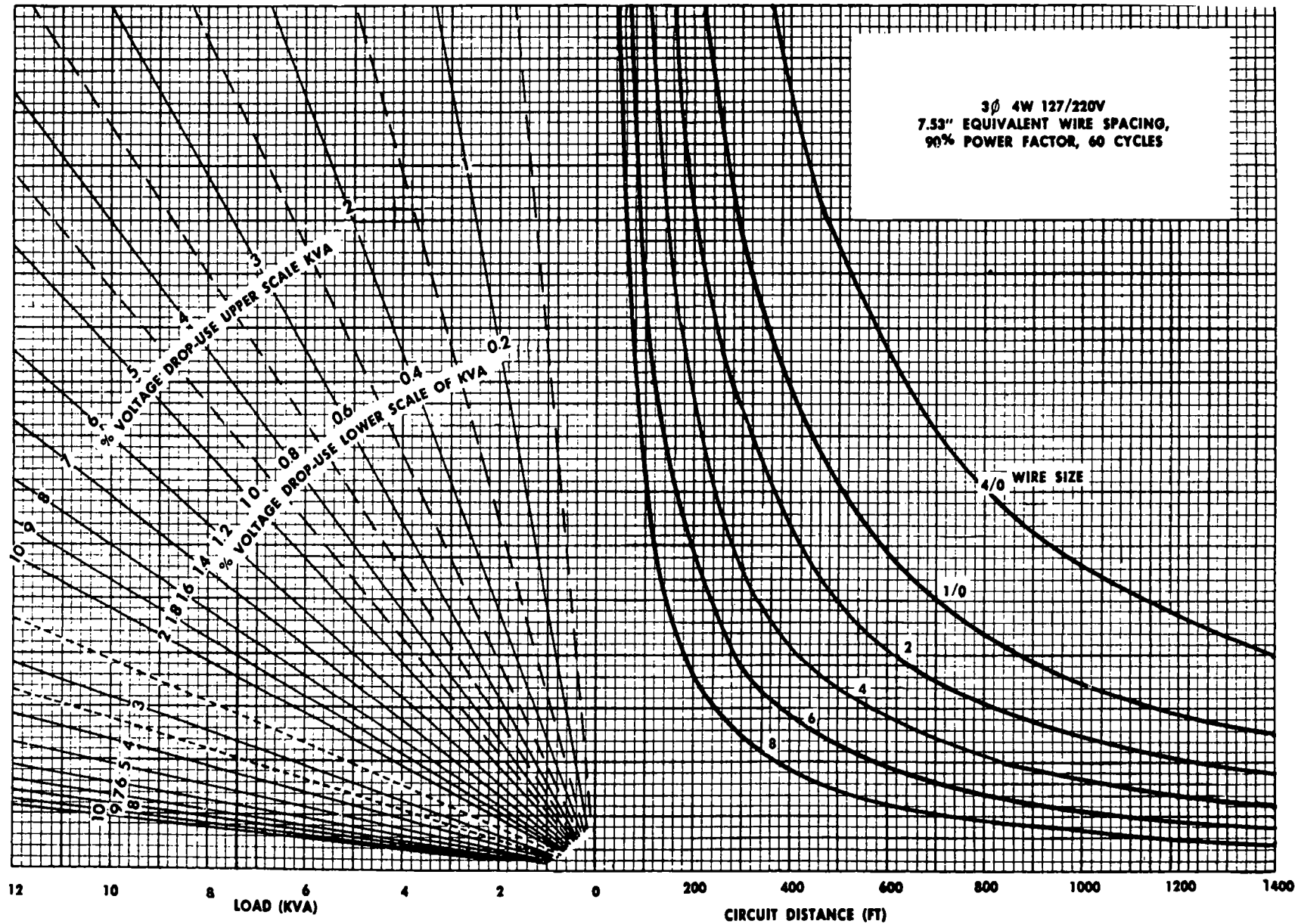


Figure 13-16. Voltage-drop and wire-size chart for single-phase two-wire 120-volt circuits.





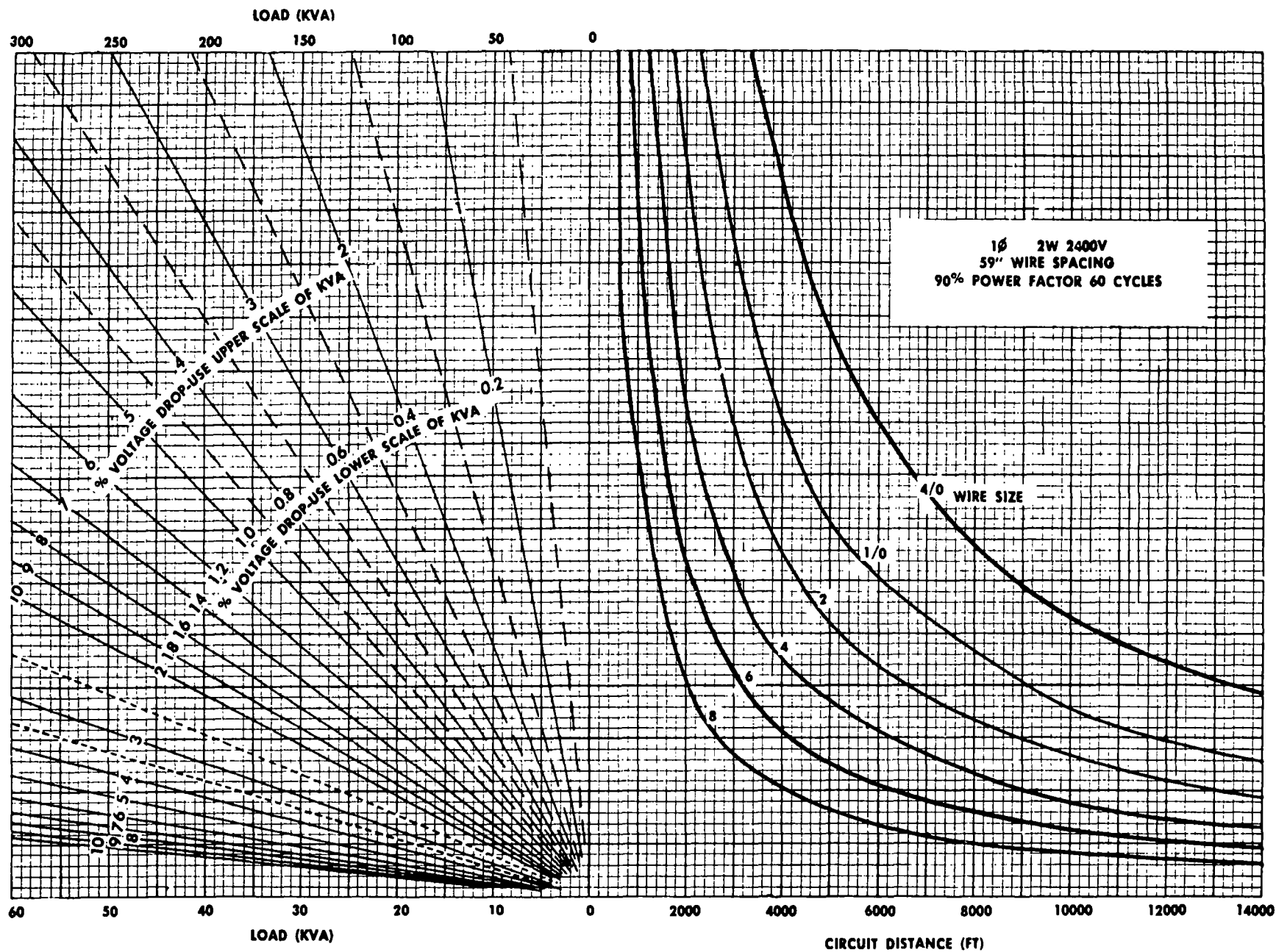


Figure 13-19. Voltage-drop and wire-size chart for single-phase two-wire 2,400-volt circuits.

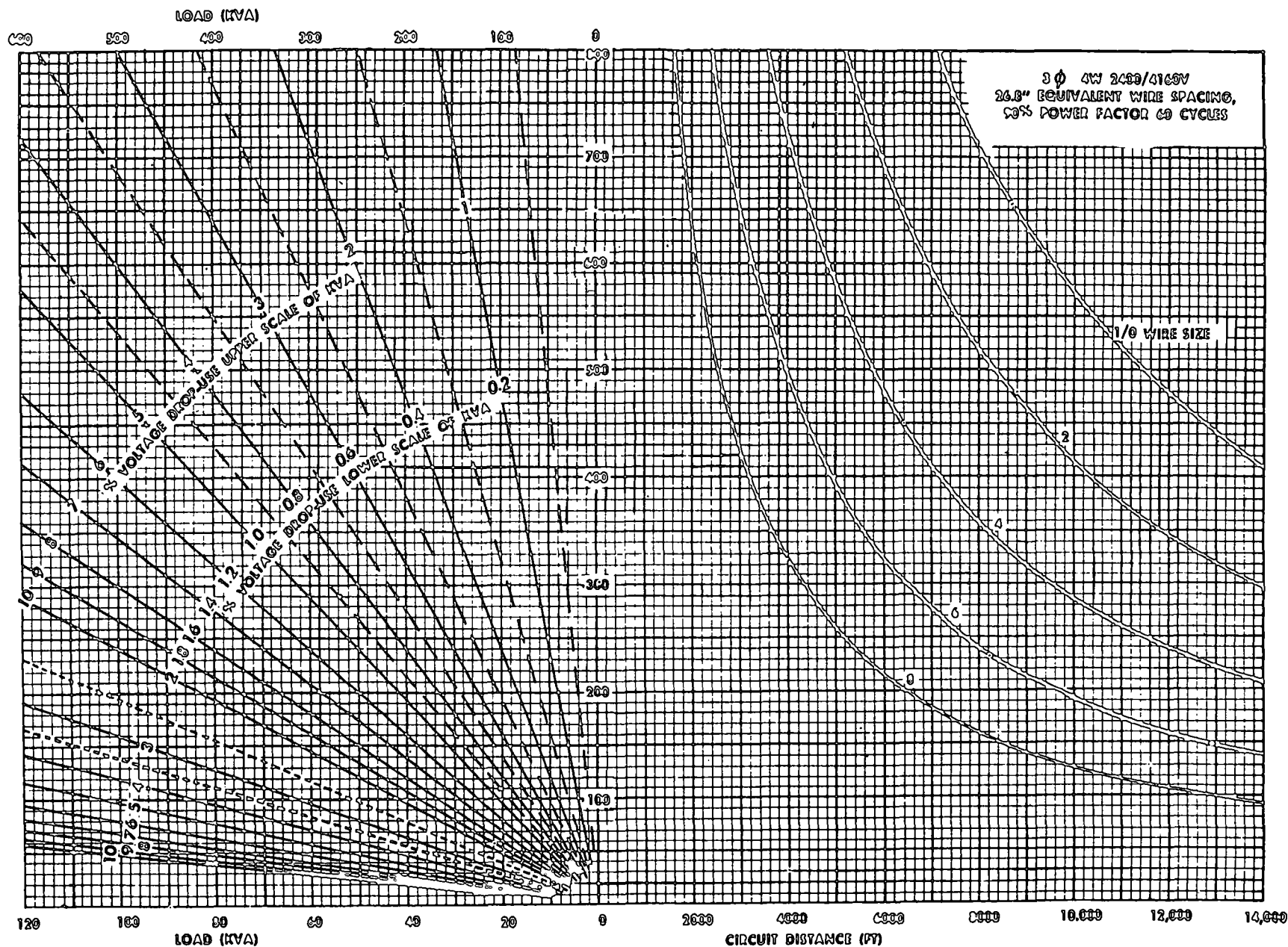


Figure 13-20. Voltage-drop and wire-size chart for three-phase four-wire 2,400/4,160-volt circuits.

Table 13-36. Wire Size Required

	Watts per circuit																					
Length of run in feet (panel box to outlet)	100	150	200	300	400	500	600	700	800	900	1000	1200	1400	1600	1800	2000	2300	2400	2600	2800	3000	3200
30 -----	14	14	14	14	14	14	14	14	14	14	14	14	14	12	12	12	12	10	10	10	10	10
40 -----	14	14	14	14	14	14	14	14	14	14	14	12	12	12	10	10	10	10	10	8	8	8
50 -----	14	14	14	14	14	14	14	14	14	12	12	12	12	10	10	10	10	8	8	8	8	8
60 -----	14	14	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	8	8	6	6
70 -----	14	14	14	14	14	14	14	12	12	12	12	10	10	8	8	8	8	8	6	6	6	6
80 -----	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	8	6	6	6	6	6
90 -----	14	14	14	14	14	12	12	12	10	10	10	10	8	8	8	6	6	6	6	6	6	4
100 -----	14	14	14	14	14	12	12	12	10	10	10	8	8	8	6	6	6	6	6	6	4	4
110 -----	14	14	14	14	14	12	12	10	10	10	10	8	8	8	6	6	6	6	6	4	4	4
120 -----	14	14	14	14	12	12	10	10	10	10	8	8	8	6	6	6	6	4	4	4	4	4
130 -----	14	14	14	14	12	12	10	10	10	8	8	8	6	6	6	6	4	4	4	4	4	4
140 -----	14	14	14	14	12	12	10	10	8	8	8	8	6	6	6	6	4	4	4	4	4	4
150 -----	14	14	14	14	12	12	10	10	8	8	8	6	6	6	6	4	4	4	4	4	4	2
160 -----	14	14	14	12	12	10	10	8	8	8	8	6	6	6	4	4	4	4	4	4	2	2
170 -----	14	14	14	12	12	10	10	8	8	8	8	6	6	6	4	4	4	4	4	2	2	2
180 -----	14	14	14	12	10	10	10	8	8	8	6	6	6	4	4	4	4	4	2	2	2	2
190 -----	14	14	14	12	10	10	8	8	8	8	6	6	4	4	4	4	4	4	2	2	2	2
200 -----	14	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	4	2	2	2	2	2
210 -----	14	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2	2	2
220 -----	14	14	14	12	10	10	8	8	8	6	6	6	4	4	4	2	2	2	2	2	2	2
230 -----	14	14	12	12	10	8	8	8	6	6	6	6	4	4	4	2	2	2	2	2	2	1
240 -----	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2	2	1	1
250 -----	14	14	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2	2	1	1

(3) *Voltage drop and wire sizes in branch circuits.* Table 13-36 gives the wire sizes required for 115-volt circuits of various lengths of run, based on a drop of not more than two volts between the panel board and the outlets.

(4) A nomograph for finding voltage drop (approximately) is given in figure 13-21.

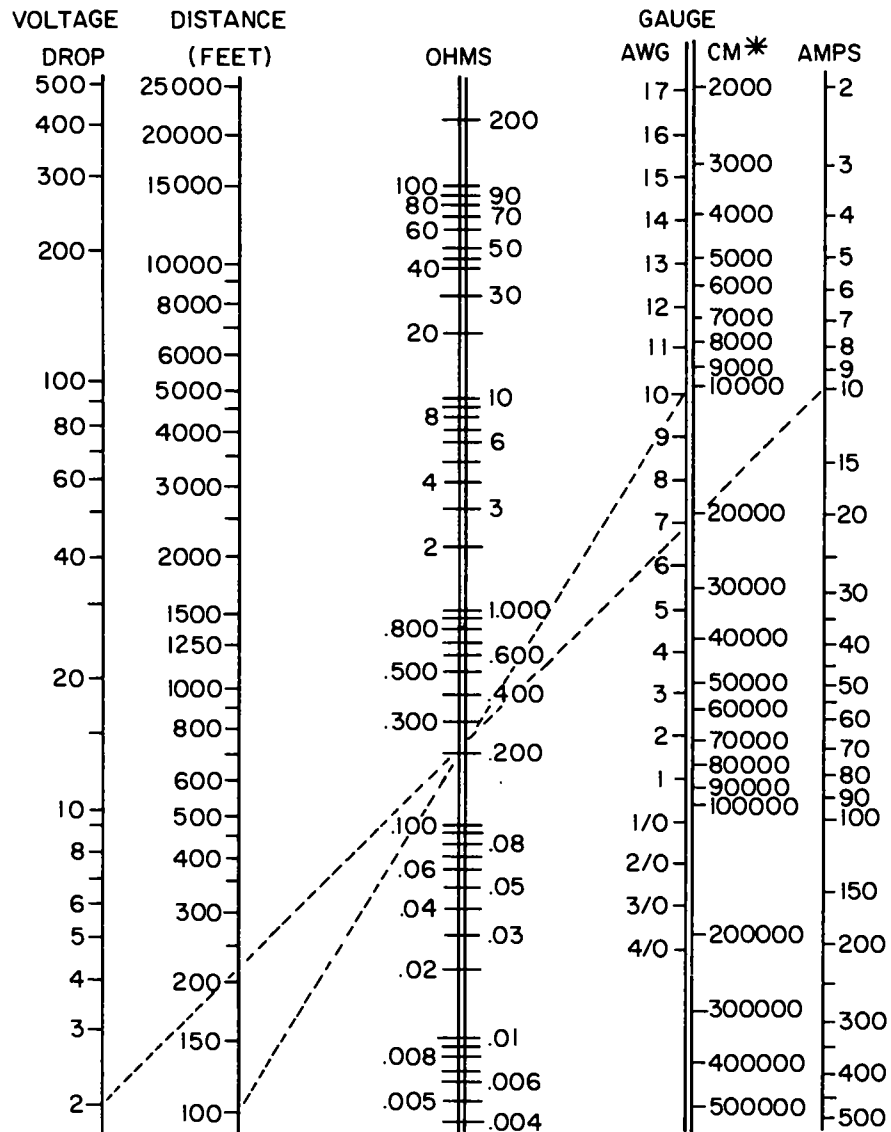
Example: to find the size of wire to carry 10 amperes 100 feet with a 2-volt drop of potential;

place a straightedge on 2-volt and 10 amperes, read .2 ohm at the intersection of the straightedge with the ohms scale; place the straightedge on .2 ohm and 100 feet, read No. 10 gage at the intersection of the straightedge with the AWG scale.

(5) Tables 13-37, 13-38, and 13-39 give wire size requirements based upon a voltage drop of approximately 3 percent.

Table 13-37. Wire Sizes for 120-Volt Single-Phase Circuit

Load (amperes)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG)												
			Distance one way from supply to load (feet)												
			50	75	100	125	150	175	200	250	300	350	400	450	500
15	14	10	14	12	10	8	8	6	6	6	4	4	4	2	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	4	4	4	2	2	2	1	1
30	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
35	12	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
40	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
45	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
50	10	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
55	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
60	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
65	8	4	6	4	4	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
70	8	4	6	4	2	2	1	1	0	2/0	2/0	3/0	4/0	4/0	
75	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
80	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
85	6	4	4	4	2	1	1	0	2/0	3/0	3/0	4/0			
90	6	2	4	2	2	1	0	0	2/0	3/0	3/0	4/0			
95	6	2	4	2	2	1	0	2/0	2/0	3/0	4/0				
100	4	2	4	2	2	1	0	2/0	2/0	3/0	4/0				



$$* \text{ CIRCULAR MILS} = \frac{\text{AMPERES} \times \text{DISTANCE IN FEET} \times 21.6}{\text{VOLTAGE DROP}}$$

Figure 13-21. Wire sizes and voltage drops.

Table 13-38. Wire Sizes for 220-Volt 3-Phase Circuits

Load (amperes)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG)												
			Distance one way from supply to load (feet)												
			100	150	200	250	300	350	400	500	600	700	800	900	1,000
15	14	12	14	12	10	8	8	8	6	6	6	4	4	4	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	6	4	4	2	2	2	2	1
30	12	8	10	8	6	6	6	4	4	2	2	2	1	1	0
35	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
40	10	6	8	6	6	4	4	4	2	1	1	1	0	0	2/0
45	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
50	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
55	8	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
60	8	6	6	6	4	2	2	2	1	0	0	2/0	3/0	3/0	4/0
65	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
70	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
75	6	4	6	4	2	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
80	6	4	6	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0	
85	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
90	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
95	6	4	6	4	2	1	1	0	2/0	3/0	3/0	4/0			
100	4	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
125	4	2	4	2	1	0	2/0	2/0	3/0	4/0					
150	2	2	2	2	0	2/0	2/0	3/0	4/0						
175	2	1	2	1	0	2/0	3/0	4/0	4/0						
200	1	0	1	0	2/0	3/0	4/0	4/0							
225	0	0	0	0	2/0	3/0	4/0								
250	2/0	2/0	2/0	2/0	3/0	4/0									
275	3/0	3/0	3/0	3/0	3/0	4/0									
300	3/0	3/0	3/0	3/0	4/0										
325	4/0	4/0	4/0	4/0											

Table 13-39. Wire Sizes for 240-Volt Single-Phase Circuits

Load (amperes)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG)												
			Distance one way from supply to load (feet)												
			100	150	200	250	300	350	400	500	600	700	800	900	1,000
15	14	10	14	12	10	9	8	6	6	6	4	4	4	2	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	4	4	4	2	2	2	1	1
30	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
35	12	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
40	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
45	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
50	10	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
55	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
60	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
65	8	4	6	4	4	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
70	8	4	6	4	2	2	1	1	0	0	2/0	3/0	4/0	4/0	
75	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
80	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
85	6	4	4	4	2	1	1	0	2/0	3/0	3/0	4/0			
90	6	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
95	6	2	4	2	2	1	0	2/0	2/0	3/0	4/0				
100	4	2	4	2	2	1	0	2/0	2/0	3/0	4/0				
125	4	2	4	2	1	0	2/0	3/0	3/0	4/0					
150	2	1	2	1	0	2/0	3/0	4/0	4/0						
175	2	0	2	0	2/0	3/0	4/0	4/0							
200	1	0	1	0	2/0	3/0	4/0								
225	1/0	2/0	1/0	2/0	3/0	4/0									
250	2/0	2/0	2/0	2/0	3/0	4/0									
275	3/0	3/0	3/0	3/0	4/0										
300	3/0	3/0	3/0	3/0	4/0										
325	4/0	4/0	4/0	4/0											

13-56. Pole Lines

a. *General.* See TM 5-765 for construction details of overhead distribution systems. In general, pole lines should be installed along streets or roads, wherever practicable, in order to avoid the need for separate poles for street lights. In connection with the selection of pole lengths, allowance should be made for the installation of telephone lines on all distribution poles. These lines are usually installed by signal unit personnel but the designer of the distribution system is responsible for the additional space and strength requirements. Specified pole lengths include the section below ground line.

b. *Depth.* Table 13-40 gives the depths to which poles of various lengths should be set in soil and in rock. Table 13-41 gives similar data for the case of rock overlaid with a thin layer of soil.

Table 13-40. Depth for Setting Pole in Soil or Rock

Height of pole (feet)	Depth of setting (feet)	
	In soil	In rock
20	5	3
25	5½	3½
30	5½	4
35	6	4
40	6	4
45	6½	4½
50	7	4½
55	7½	5
60	8	5

Table 13-41. Division of Setting Depth in Feet Between Soil and Rock

30-foot pole		40-foot pole		50-foot pole		60-foot pole	
Soil	Rock	Soil	Rock	Soil	Rock	Soil	Rock
0	4	0	4	0	4½	0	5
1	4	1	4	1	4½	1	5
2	3	2	3	2	4	2	4½
3	2	3	2	3	3	3	4
4	1½	4	1½	4	2½	4	3
		5	1	5	2	5	2
				6	1	6	1½
						7	1

c. *Strength.* The class of pole is determined on the basis of its ultimate breaking strength at the ground line as listed in table 13-42. Poles should have four times the strength required to support the actual vertical and transverse loading, except when the poles are guyed. The guy should support the entire load in the direction in which it acts, the pole simply acting as a strut. See *k* below for characteristics of guys.

d. *Footings.* Foundations for vertical loads, including the vertical components of guys, must be adequate to prevent the pole from sinking into

Table 13-42. Breaking Strength of Classified Poles

Class	Load, pound force
1	4,500.
2	3,700.
3	3,000.
4	2,400
5	1,900.
6	1,500.
7	1,200.
8 to 10	Not specified.

the ground. When the area of the butt of a pole is too small to bear the vertical load without sinking, a pole footing of planks or concrete is installed under the butt. Existing poles need not be reinforced unless observed to be sinking. The alignment chart in figure 13-22 is used to determine adequate support for vertical loads in various types of soil. The pole circumference at the ground line is used as a measure of bearing area. For example, as shown by the dotted line in the alignment chart, a pole bearing a vertical load of 8,000 pounds in sandy soil requires a pole footing with a ground-line circumference of 45 inches. If the class of pole in use or available for use has a circumference smaller than 45 inches, a pole footing similar to the illustrated should be used to provide the necessary bearing

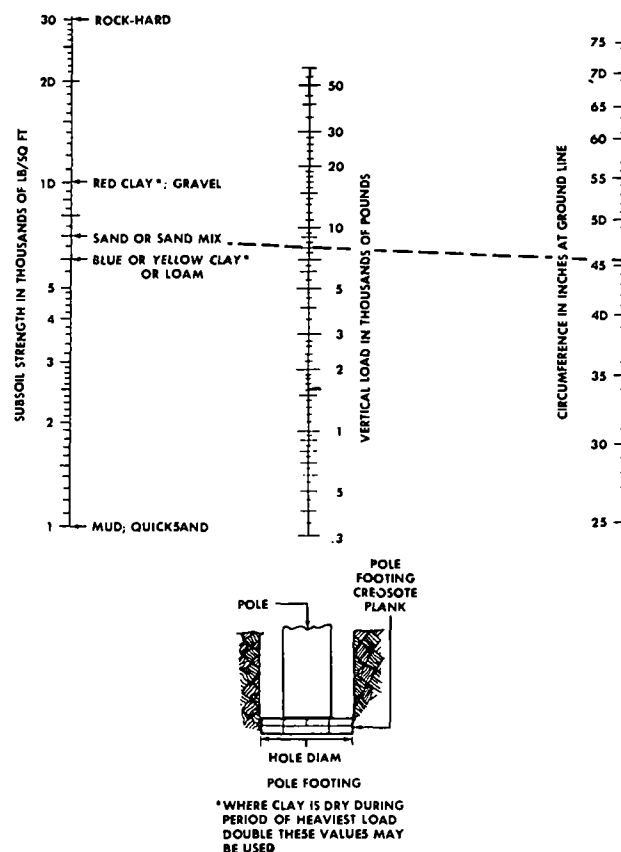
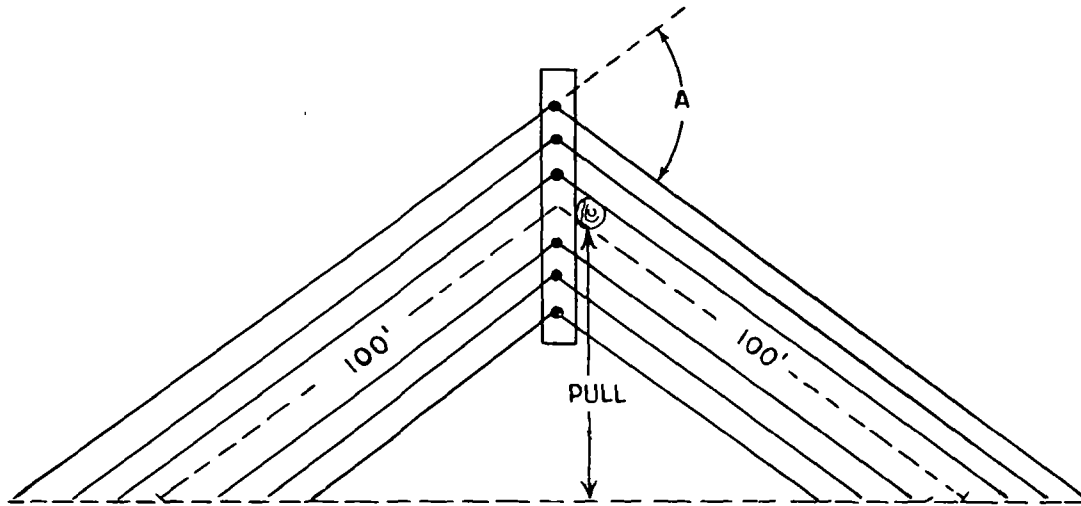


Figure 13-22. Alinement chart for pole or pole-footing diameters.

area. By laying a straightedge across the alignment chart a third condition can be determined if any two are known.

e. Pole Spacing. Poles are spaced at about 125 feet in a straight pole line. The usual maximum

is 150 feet; the minimum about 100 feet. In curves and at corners the spacing is reduced as shown in figure 13-23. For relatively long lines and light loads spans up to 200 or 250 feet are used; and up to 400 or 500 feet when steel-reinforced aluminum cable is used.



NOTE: If the "PULL" is less than 5', the spans adjacent to the angle pole may be standard 125' length. If the "PULL" exceeds 5', the spans adjacent to the angle pole shall be reduced to the distance given in the table.

ANGLE A	PULL IN FEET	SPAN FEET	NO OF 6000 # SIDE GUYS		
			1 ARM 6 WIRES	2 ARMS 12 WIRES	3 ARMS 18 WIRES
Less Than 6°	Less Than 5'	125	None	None	None
6° - 11°	5' - 10'	115	None	1	1
11° - 15°	10' - 13'	105	1	1	1
15° - 22°	13' - 19'	95	1	1	2
22° - 30°	19' - 26'	85	1	1	2
Over 30°	Over 26'	75	1	2	2

Figure 13-23. Pole spacing and side guys on curves.

f. Wire Spacing. Three- and four-wire circuits normally are carried on poles without crossarms, using strain type insulator clevises spaced as shown in figure 13-24.

g. Wire Clearances Aboveground. Minimum allowable clearances under various conditions are given in figure 13-25.

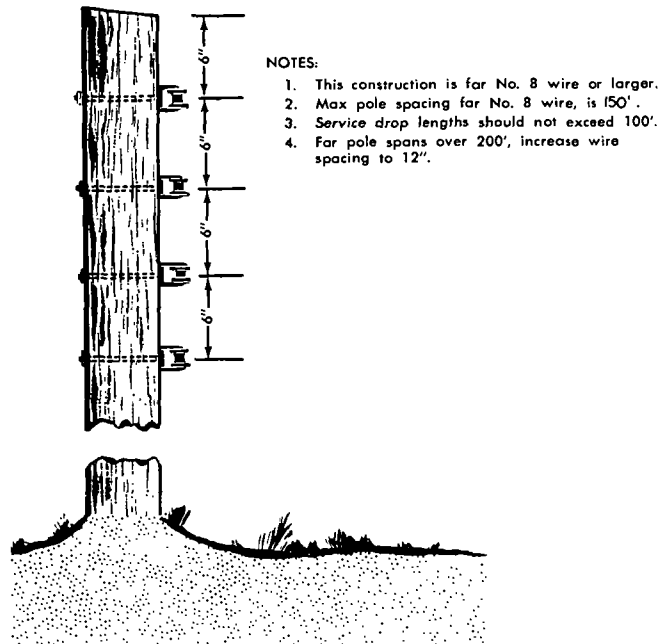
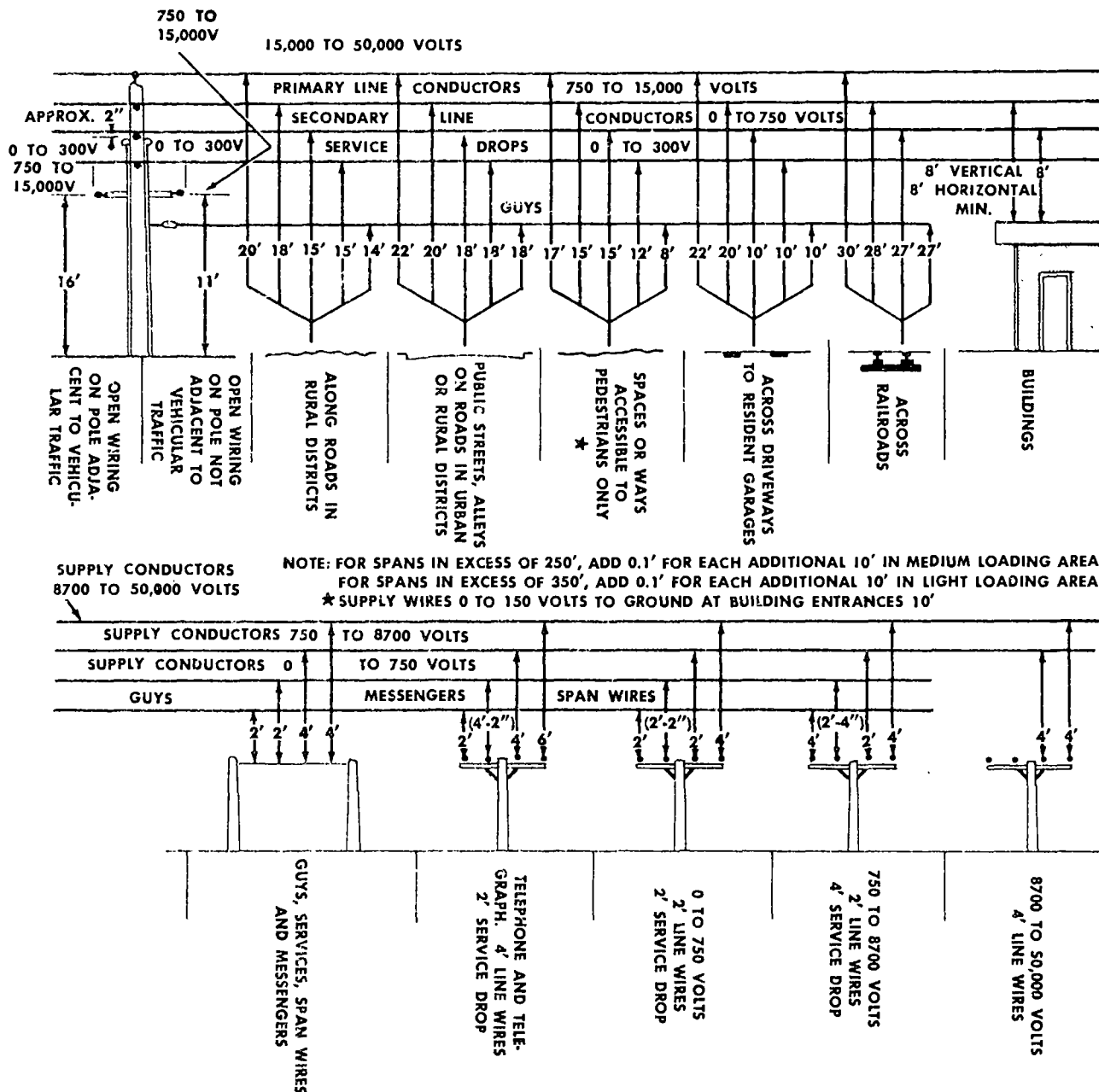


Figure 13-24. Wire spacing on poles.



NOTES: 1. THE ABOVE CLEARANCES APPLY WHERE THE SPAN LENGTH OF THE UPPER CONDUCTOR DOES NOT EXCEED 250' FOR MEDIUM LOADING AREA AND 350' FOR LIGHT LOADING AREA. FOR LONGER SPANS, INCREASE THE CLEARANCE 0.15' FOR MEDIUM LOADING AND 0.10' FOR LIGHT LOADING AREA FOR EACH 10' IN SPAN LENGTH.

2. CLEARANCE MARKED () INDICATES THAT IN GENERAL THE LINES OPERATING AT THE CORRESPONDING VOLTAGE SHOULD NOT CROSS OVER LINES AT THE HIGHER VOLTAGE.

Figure 13-25. Minimum clearances of conductors.

h. Wire. Diameters, weights, and resistances of wires normally used in overhead distribution systems are given in tables 13-43 through 13-47.

i. Sag. Sags in inches for various wire sizes, stringing temperatures, and span lengths, based on hard- and medium-drawn insulated copper wire, are shown in table 13-48.

j. Tension. The tension in an overhead wire, in parts of the weight of the wire span including any insulation and ice coating, and for various sag ratios is shown in table 13-49. The table also gives the vertical angle at which the wire leaves

Table 13-48. Bare Solid Copper Wire

Size (AWG)	Diameter (inches)	Weight (pounds per 1,000 feet)	Resistance (ohms per 1,000 feet at 20°C)
4/0 -----	0.4600	639.8	0.04893
3/0 -----	.4096	507.3	.06170
2/0 -----	.3648	402.4	.07780
1/0 -----	.3250	319.4	.09811
1 -----	.2893	253.0	.1237
2 -----	.2576	200.6	.1560
3 -----	.2294	159.1	.1967
4 -----	.2043	126.2	.2420
5 -----	.1819	100.0	.3128
6 -----	.1620	79.35	.3944
7 -----	.1443	62.96	.4973
8 -----	.1285	49.92	.6271

Table 13-44. Weatherproof Solid Copper Wire

Size (AWG)	Diameter over insulation (inches)		Weight (pounds per 1,000 feet)		Resistance (ohms per 1,000 feet at 20°C)
	Three-braid	Two-braid	Three-braid	Two-braid	
4/0 -----	0.640	.609	767	723	0.04893
3/0 -----	.593	.562	629	587	.06170
2/0 -----	.515	.500	502	467	.07780
1/0 -----	.500	.468	407	377	.09811
1 -----	.453	.422	316	294	.12370
2 -----	.437	.390	260	239	.15600
3 -----	.406	.359	199	185	.19670
4 -----	.359	.328	.64	151	.24800
6 -----	.328	.296	112	100	.39440
8 -----	.296	.250	75	66	.62710

Table 13-45. Bare Stranded Copper Wire

Size (AWG)	Diameter (inches)	Weight (pounds per 1,000 feet)	Resistance (ohms per 1,000 feet at 20°C)	Wires in strand
4/0 -----	0.5275	653.14	0.04997	19
3/0 -----	.4644	412.07	.6293	7
2/0 -----	.4134	406.98	.07935	7
1/0 -----	.3684	322.39	.10007	7
1 -----	.3279	255.45	.12617	7
2 -----	.2919	202.50	.15725	7
3 -----	.2601	160.60	.19827	7
4 -----	.2316	127.40	.25000	7
6 -----	.1836	80.10	.39767	7

the pole, for plotting the vertical and horizontal components of the tension.

k. Guys and guy loads. The ordinary guying of poles at bends in lines is covered in *e* above. For heavier loads, dead ends, corners, and the like, find the resultant horizontal load by a parallelogram of forces, determine the guy slope practicable, and select guys from figure 13-26.

Table 13-46. Weatherproof Stranded Copper Wire

Size (AWG)	Diameter over insulation (inches)		Wires in strand	Weight (pounds per 1,000 feet)		Resistance (ohms per 1,000 feet at 20°C)
	Three-braid	Two-braid		Three-braid	Two-braid	
4/0 -----	0.812	0.687	19	800	745	0.04997
3/0 -----	.734	.671	7	653	604	.06293
2/0 -----	.687	.625	7	522	482	.07935
1/0 -----	.640	.578	7	424	388	.10007
1 -----	.593	.531	7	328	303	.12617
2 -----	.531	.468	7	270	246	.15725
3 -----	.468	.421	7	206	190	.19827
4 -----	.437	.390	7	.70	155	.25000
6 -----	.406	.359	7	115	103	.39767

Table 13-47. Bare Solid Steel Wire

Size (BWG)	Approximate diameter (inches)	Weight (pounds per 1,000 feet)	Current load (amperes)			
			1	2.5	5	10
			Resistance (ohms per mile at 20°C)			
4 -----	0.238	154	7.48	7.59	7.92	9.23
6 -----	.203	112	10.15	10.42	10.79	12.47
8 -----	.165	73.5	15.06	15.26	15.71	18.35

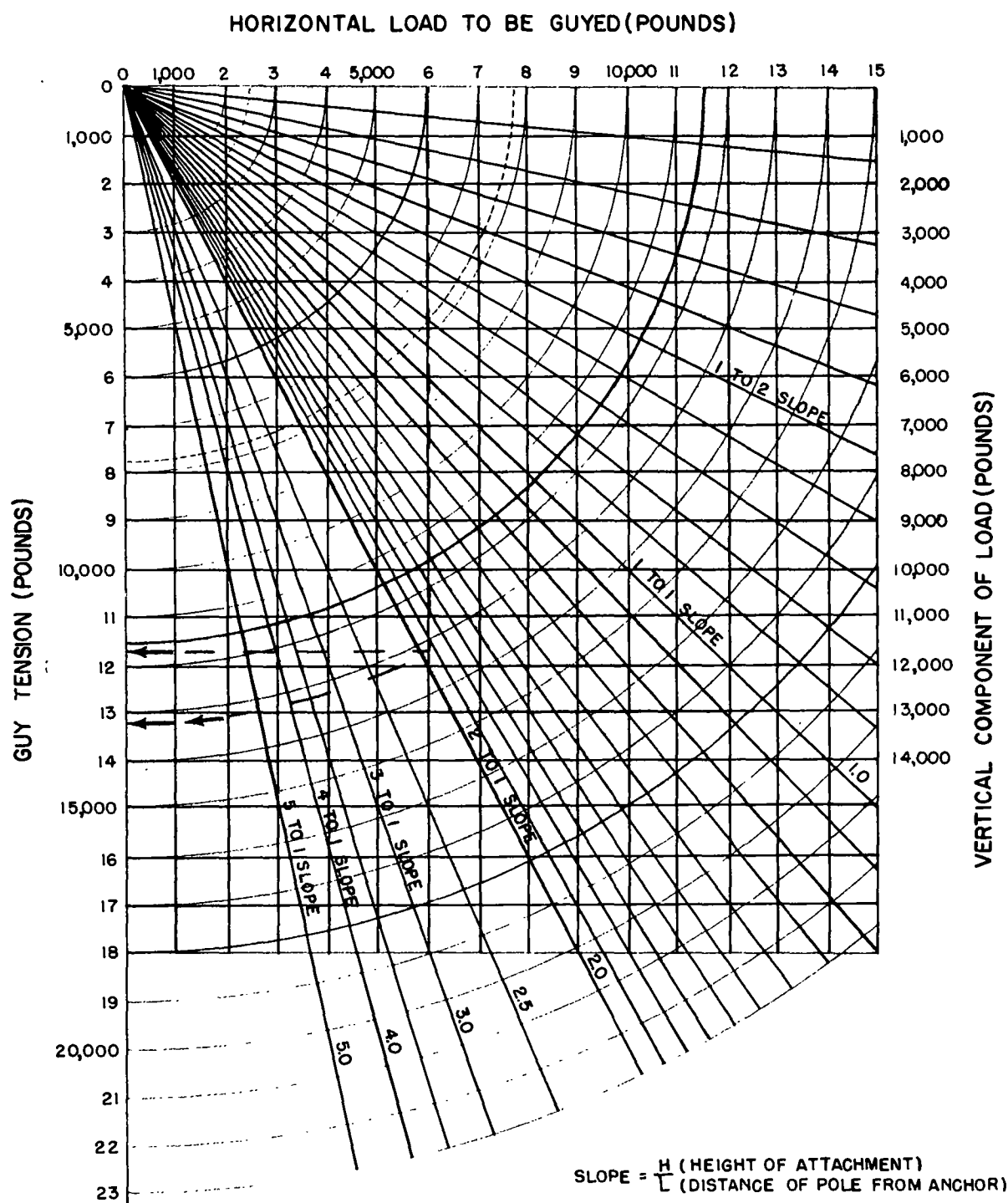
Table 13-48. Wire Sag in Inches

Wire size AWG	Stringing temp °F	Frigid and Temp Zone						Tropical Zones							
		Spans						Spans							
		100'	125'	150'	175'	200'	250'	300'	100'	125'	150'	175'	200'	250'	300'
8 -----	30	15	23	36	-----	-----	-----	-----	8.5	14	22.5	31	-----	-----	-----
	60	18	37	40	-----	-----	-----	-----	12	18	27	36	-----	-----	-----
	90	21.5	31	44	-----	-----	-----	-----	15.5	22.5	32	41	-----	-----	-----
6 -----	30	8.5	14	22	31	-----	-----	-----	6	9	14	19.5	26	-----	-----
	60	12	18	27	36	-----	-----	-----	8	12	18	24	32	-----	-----
	90	15.5	22.5	32	40	-----	-----	-----	11	16	22.5	29	38	-----	-----
4 -----	30	8.5	14	21.5	31	43	-----	-----	6.5	9	14	19	26	-----	-----
	60	12	18	27	36	48	-----	-----	8	12	18	24	32	-----	-----
	90	17	22.5	32	41	54	-----	-----	11.5	16	22	30	38	-----	-----
2 -----	30	8.5	14	21.5	23.5	30	53	89	6.5	9	14	17.5	21	28	45
	60	12	18	27	30	36	60	96	8	12	18	22	26	34	52
	90	17	22.5	32	35	42	67	103	11.5	16	22	27	32	41	60
1 -----	30	8.5	13.5	20.5	22.5	26	42	66	5.5	9	13.5	16.5	19	26	38
	60	12	18	26	28	32	49	72	8	12	18	21	24	31	45
	90	15.5	22.5	31	34	38	56	82	11.5	16	23	26	30	38	53
1/0 -----	30	8.5	13.5	20.5	22.5	26	42	66	5.5	9	14	16.5	18	24.5	34
	60	12	18	26	28	32	49	72	8	12	18	21	23	30	41
	90	15.5	22.5	31	34	38	56	82	11.5	16.5	23	27	28	36	47
2/0 -----	30	8.5	13.5	20	22.5	25	38	57	5.5	9	13.5	16	17.5	23	31
	60	12	18	25	28	31	46	66	8	12	18	20	22	28	37
	90	16	22.5	30	34	38	53	73	11.5	16	23	25	28	35	45
4/0 -----	30	8.5	13.5	18.5	21	24.5	31	43	5.5	8.5	13.5	16	16.5	20.5	27
	60	12	18	24	27	30	38	50	8	12	18	19	21	25	32
	90	16	22.5	29	33	36	46	59	11.5	16	23	24.5	26	31	39

Table 13-49. Wire-Sag Tension

Sag in parts of the span	Sag in decimal parts of span	Tension at pole in parts of the weight of the span of wire	Vertical angle of wire leaving pole		Length of wire in parts of span
			Deg.	Min.	
1/300 -----	0.00333	37.5	0	46	¹ 1.00
1/200 -----	.005	25.0	1	09	¹ 1.00
1/150 -----	.0067	18.8	1	32	¹ 1.00
1/125 -----	.008	15.6	1	50	¹ 1.00
1/100 -----	.01	12.5	2	18	¹ 1.00
1/80 -----	.0125	10.0	2	52	¹ 1.00
1/67.5 -----	.015	8.45	3	23	¹ 1.00
1/50 -----	.02	6.27	4	35	¹ 1.00
1/40 -----	.025	5.03	5	43	¹ 1.00
1/35 -----	.0286	4.40	6	31	¹ 1.00
1/30 -----	.0333	3.78	7	36	¹ 1.00
1/25 -----	.04	3.16	9	06	¹ 1.00
1/20 -----	.05	2.55	11	19	1.01
1/15 -----	.0667	1.94	14	55	1.01
1/10 -----	.1	1.35	21	48	1.03
1/5 -----	.2	.800	38	40	1.10
1/4 -----	.25	.707	45	00	1.15
1/3 -----	.333	.625	53	08	1.25
1/2 -----	.5	.559	63	26	1.48

¹ Less than 1.005.

**DIRECTIONS**

1. FIND LOAD TO BE GUYED ON TOP SCALE (ACTUAL LOAD X SAFETY FACTOR)
2. PROCEED VERTICALLY TO LINE FOR SLOPE OF GUY AREA IN WHICH THIS POINT LIES INDICATES THE PROPER SIZE OF GUY
3. FIND TENSION IN GUY WIRE BY FOLLOWING CIRCLE
4. FIND THE VERTICAL COMPONENT OF THE LOAD BY FOLLOWING A HORIZONTAL LINE TO THE SCALE ON THE LEFT

Figure 13-26. Load held by various guy strands at any slope.

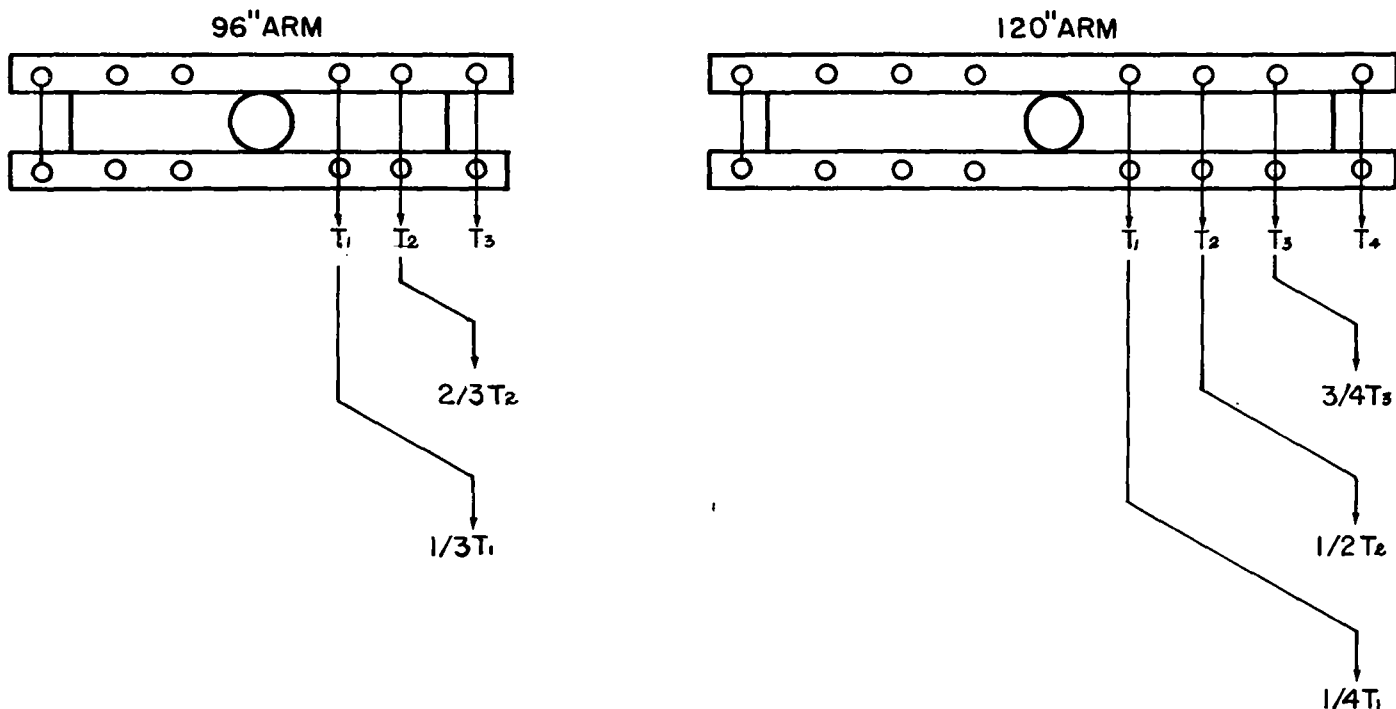


Figure 13-27. Equivalent load at end-pin position.

1. *Crossarms.* See TM 5-765 for additional data. All crossarm loads are reduced to an equivalent load on the end pin, horizontally and vertically, and the horizontal unbalance is determined as shown in figure 13-27. The required crossarm size or any necessary doubling of crossarms is then selected from tables 13-50 and 13-51.

Table 13-50. Maximum Loads on Single Arms Without Arm Guys

Cross arm size (inches)	Equivalent maximum allowable horizontal load at end of pin (pounds)	Equivalent maximum allowable unbalanced horizontal load at end of pin (pounds)	Equivalent maximum allowable vertical load at end of pin (pounds)
38 x 3 1/4 x 4 1/4 ----	900	600	1,000
38 x 3 1/2 x 4 1/4 ----	1,000	600	1,150
38 x 3 3/4 x 4 3/4 ----	1,300	600	1,250
67 x 3 1/4 x 4 1/4 ----	500	400	800
67 x 3 1/2 x 4 1/2 ----	600	400	900
67 x 3 3/4 x 4 3/4 ----	700	400	1,000
96 x 3 1/4 x 4 1/4 ----	400	250	600
96 x 3 1/2 x 4 1/2 ----	500	250	750
96 x 3 3/4 x 4 3/4 ----	600	250	850
120 x 3 1/2 x 4 1/2 ----	300	200	550
120 x 3 3/4 x 4 3/4 ----	400	200	650
120 x 4 x 5 ----	500	200	750

Table 13-51. Maximum Loads on Double Arms Without Arm Guys

Cross arm size (inches)	Equivalent maximum allowable horizontal load at end of pin (pounds)	Equivalent maximum allowable unbalanced horizontal load at end of pin (pounds)	Equivalent maximum allowable vertical load at end of pin (pounds)
38 x 3 1/4 x 4 1/4 ----	3,600	1,000	2,000
38 x 3 1/2 x 4 1/2 ----	4,350	1,000	2,300
38 x 3 3/4 x 4 3/4 ----	5,200	1,000	2,500
67 x 3 1/4 x 4 1/4 ----	1,850	600	1,600
67 x 3 1/2 x 4 1/2 ----	2,200	600	1,800
67 x 3 3/4 x 4 3/4 ----	2,650	600	2,000
96 x 3 1/4 x 4 1/4 ----	1,250	400	1,200
96 x 3 1/2 x 4 1/2 ----	1,450	400	1,500
96 x 3 3/4 x 4 3/4 ----	1,750	400	1,700
120 x 3 1/2 x 4 1/2 ----	1,100	300	1,100
120 x 3 3/4 x 4 3/4 ----	1,350	300	1,300
120 x 4 x 5 ----	1,600	300	1,500

13-57. Lighting in Theater-of-Operations Construction

Where facilities permit, the following wattages are suggested for lighting in theater-of-operations buildings.

	Watts per square foot of floor area
Barracks, quarters	0.10
Storage, wards, heater, toilets, warehouses ..	.20

	Watts per square foot of floor area
Messhalls, waiting, and living spaces	.30
Recreation, bathhouses, kitchens, general work spaces, noncritical	.50
Reading, laboratories, barber, tailor, post exchange, pharmacy, work spaces	.75
Offices, laundry, shops—low mounting heights up to 10 feet(repair or production	1.00

13-58. Miscellaneous Electrical Data

a. *Number of Insulated Wires Allowed in Various Sized Conduits.* See table 13-52.

b. *Number of Conductors in a Box.*

(1) Table 13-53 gives the maximum number of conductors, not counting fixture wires, permitted in outlet and junction boxes. This table

Table 13-52. Number of Insulated Wires Allowed in Various Sized Conduits

Size AWG MCM	1	Number of conductors in one conduit or tubing							
		2	3	4	5	6	7	8	9
18	1½	1½	1½	1½	1½	1½	1½	¾	¾
16	1½	1½	1½	1½	1½	1½	¾	¾	¾
14	1½	1½	1½	1½	¾	¾	1	1	1
12	1½	1½	1½	¾	¾	1	1	1	1½
10	1½	¾	¾	¾	1	1	1	1½	1½
8	1½	¾	¾	1	1½	1½	1½	1½	1½
6	1½	1	1	1½	1½	1½	2	2	2
4	1½	1½	1½	1½	1½	2	2	2	2½
3	¾	1½	1½	1½	2	2	2	2½	2½
2	¾	1½	1½	2	2	2	2½	2½	2½
1	¾	1½	1½	2	2½	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1½	2	2½	3	3	3	3½	3½	4
250	1½	2½	2½	3	3	3½	4	4	5
300	1½	2½	2½	3	3½	4	4	5	5
350	1½	3	3	3½	3½	4	5	5	5
400	1½	3	3	3½	4	4	5	5	5
500	1½	3	3	3½	4	5	5	5	6

applies where no fittings or devices, such as fixture studs, cable clamps, hickey, switches, or receptacles are contained in the box. Where one or more fixture studs, cable clamps, or hickey are contained in the box, the number of conductors shall be one less than shown in the tables, with a further deduction of one conductor for one or several flush devices mounted on the same strap. A conductor running through the box is counted as one conductor and each conductor originating outside the box and terminating inside the box is counted as one conductor. Conductors of which no part leaves the box are not to be counted in the above computation. If single flush boxes are ganged, and each section is occupied by a flush device or combination of flush devices on the same strap, the limitations will apply to each section individually.

(2) Table 13-54 applies for combinations not shown in table 13-53.

c. *Full-Load Current and Circuit-Breaker Sizes for Alternating-Current Motors.* See table 13-55.

Table 13-53. Number of Conductors Allowed in Boxes of Certain Sizes

Box dimensions—trade size	Maximum number of conductors			
	No. 14	No. 12	No. 10	No. 8
1½ x 3¼ octagonal	5	5	4	0
1½ x 4 octagonal	8	7	6	5
1¼ x 4 square	9	7	6	4
1½ x 4 square	11	9	7	5
1½ x 4½ square	16	12	10	8
2½ x 4½ square	20	16	12	10
2 x 1¾ x 2¾	5	4	4	-----
2½ x 1¾ x 2¾	6	6	5	-----
3 x 1¾ x 2¾	7	7	6	-----

Where there is not sufficient space for a deeper box, four No. 14 AWG conductors may enter a box provided with cable clamps and containing one or more devices on a single mounting strap.

Shallow Boxes of Less Than 1½" Depth

Box dimensions—trade size	Maximum number of conductors		
	No. 14	No. 12	No. 10
3¼	4	4	3
4	6	6	4
4½	8	6	6

Table 13-54. Number of Conductors Allowed in Boxes,
Other Combinations

Size of conductor	Free space within box for each conductor
No. 14 -----	2 cubic inches.
No. 12 -----	2.25 cubic inches.
No. 10 -----	2.5 cubic inches.
No. 8 -----	3 cubic inches.

Table 13-55. Full-Load Current and Circuit-Breaker Sizes for Alternating-Current Motors

Motor horsepower	Single phase				Three phase			
	110 volt		220 volt		220 volt		440 volt	
	Current (amps)	Circuit-breaker size (amps)	Current (amps)	Circuit-breaker size (amps)	Current (amps)	Circuit-breaker size (amps)	Current (amps)	Circuit-breaker size (amps)
1/6 -----	3.34	15	1.67	15	-----	-----	-----	-----
1/4 -----	4.8	15	2.4	15	-----	-----	-----	-----
1/2 -----	7	15	3.5	15	2.5	15	1.3	15
3/4 -----	9.4	25	4.7	15	2.8	15	1.4	15
1 -----	11	25	5.5	15	3.3	15	1.7	15
1 1/2 -----	15.2	35	7.6	25	4.7	15	2.4	15
2 -----	20	50	10	25	6	15	3	15
3 -----	28	50	14	35	9	25	4.5	15
5 -----	46	70	23	50	15	35	7.5	15
7 1/2 -----	68	125	34	70	22	50	11	25
10 -----	86	200	43	70	27	50	14	35
15 -----	-----	-----	-----	-----	38	70	19	50
20 -----	-----	-----	-----	-----	52	125	26	70
25 -----	-----	-----	-----	-----	64	125	32	70
30 -----	-----	-----	-----	-----	77	125	39	70
40 -----	-----	-----	-----	-----	101	200	51	125
50 -----	-----	-----	-----	-----	125	200	63	125
60 -----	-----	-----	-----	-----	149	225	75	125
75 -----	-----	-----	-----	-----	180	400	90	200
100 -----	-----	-----	-----	-----	246	400	123	200

Section V. SPECIAL UTILITIES

13-59. Refrigerated Warehouses

a. *References.* TM 5-302 includes details on construction of refrigerated warehouses. Table 13-56 gives sizes and capacities of standard theater of operations refrigerated warehouses.

b. *Types and Capacities.* For preliminary planning in areas where refrigerated storage is needed primarily for frozen meat, a storage capacity of 0.02 cubic feet per man per day is satisfactory. For storing all components of the

Table 13-56. Sizes and Capacities of TO Refrigerated Warehouses, Standard Frame

Nominal size	20' x 55'	20' x 100'	80' x 220'
Inside dimensions (feet) -----	18' x 40' -----	18' x 88' -----	77.5' x 197' -----
Gross floor area (square feet) -----	720 -----	1,584 -----	15,267 -----
Ceiling height (feet) -----	8 -----	8 -----	14.5 -----
Height of stack (feet) -----	6 -----	6 -----	12 -----
Equipment -----	2 compressors (20,000 B.t.u. per hour). 1 evap condenser ----- 1 cooling tower ----- 2 unit coolers -----	2 compressors (40,000 B.t.u. per hour). 1 evap condenser ----- 1 cooling tower ----- 4 unit coolers -----	1 compressor (78,000 B.t.u. per hour). 2 compressors (180,000 B.t.u. per hour). 1 evap condenser. 1 receiver. 20 unit coolers.

Table 13-56. Sizes and Capacities of TO Refrigerated Warehouses, Standard Frame—Continued

Nominal size	20' x 55'	20' x 100'	80' x 220'
Storage capacity			
Frozen packaged boned beef:			
Total pounds	81,000	178,200	
Total rations	162,000	356,400	
Men for 60 days	2,700	5,940	
Butter and shelled eggs:			
Total pounds, butter	36,000	79,200	
Total pounds, eggs	36,000	79,200	
Total combined rations	288,000	633,600	
Men for 60 days	4,800	10,560	
Ham, bacon, bologna, potatoes, onions, and citrus fruits. ¹			
Total pounds, ham, bacon and bologna.	10,200	22,440	
Total pounds, other items	45,500	100,030	
Total combined rations	65,000	142,900	
Men for 60 days	1,080	2,380	

¹ Equal rations of each item.

field ration, at least three compartments are needed; one for frozen meat because of the low temperature required, one for butter and shelled eggs because they are contaminated easily by other foods, and one for smoked meats, fruits, and vegetables. The controls are normally operated to maintain temperatures of 10° F for frozen meat and 34° F for other foods.

c. Illustrative Situations.

(1) *Problem.* To select refrigerated warehouse capacity suitable for 30-day storage of rations for 20,000 men.

(2) *Solution.* This is equivalent to 60-day storage for 10,000 men. Table 13-56 shows that the following are adequate—

	<i>Rations (men for 60 days)</i>
For frozen beef, 2 warehouses 20' x 100'	11,880
For butter and shelled eggs, 1 warehouse 20' x 100'	10,560
All other items:	
4 warehouses 20' x 100'	9,520
1 warehouse 20' x 55'	1,080

d. *Refrigerants and Iceplants.* Table 13-57 gives properties of refrigerants and table 13-58 gives the characteristics of iceplants.

Table 13-57. Refrigerant Properties

	Ammonia (NH ₃)	Freon (F-12) (CCl ₂ F ₂)	Freon (F-22) CHClF ₂	Methylchloride (CH ₂ Cl)
Critical temperature	271°F	233°F	204.8°F	290°F.
Flammability	Burns if heated. May explode under certain conditions.	Nonflammable and nonexplosive.	Nonflammable and nonexplosive.	Flammable but does not burn readily. Explosive under certain conditions.
Effect on metals	Reacts with copper and brass if water vapor is present. Slight effect on iron and steel.	Noncorrosive	Noncorrosive	Noncorrosive.
Effect on lubricants ..	No effect if ammonia is anhydrous. If moisture is present, tends to form emulsion.	No effect. Mixes with oil in all proportions.	No effect. Mixes with oil in all proportions.	Dissolves all kinds of oil. Glycerine and white mineral oils must be used.
Effect on personnel ..	Injurious if exposure is prolonged and gas concentration is above 1/30 of 1 percent. Very irritating to eyes and nose.	Practically non-toxic.	Practically non-toxic.	Concentration of 2 percent to 2½ percent for 2 hours may cause death.
Tests for leaks	By smell. Exact location found with sulfur candles. ¹	(²)	(²)	Smells like chloroform. Alcohol flame in methyl chloride has greenish tinge.

¹ Forms white fog when burned in presence of ammonia.² Halide lamp usually used. This consists of a flame-heated copper wire which in contact with freon burns with a blue-green color.

Table 13-58. Iceplants

	1-ton	3.6-ton	15-ton
Stock No	66-5710. 01-0	66-5710. 06-0	66-5710. 15-0
Weight (pounds crated for export)	10,200	27,500	120,600
Cubage (cubic feet crated for export)	427	1,314	4,950
Connected electrical load ..	None	12.24 kva 11.40 kva	57.76 55.26

13-60. Air Conditioning

a. Authorized Uses. Air conditioning is used in theater-of-operations buildings and in mobile vans and shelters housing electronic communications, data processing, photographic darkrooms, machine records units, and similar critical operations and in field hospitals. In general it will be used in such installations where without air conditioning the effective temperature would rise above 85° F (ET) and result in unacceptable levels of heat stress in individuals and/or be likely to damage or render inoperative or ineffective the installed equipment. Effective temperature (ET) depends on the integration of dry bulb temperature, humidity, and air movement as discussed in American Society of Refrigeration Air Conditioning Engineers (ASHRAE) Guide and Data Book, Fundamentals and Equipment for 1965 and 1966.

b. Standard Family of Air Conditioners. A family of standard military air conditioners is available and will be used where authorized and justified in the proper capacity and electrical type and configuration. This family includes compact vertical and horizontal configuration types in 9,000; 18,000; 36,000 and 60,000 BTUH. A 6,000 BTUH unit is also available in the vertical configuration only. All units incorporate electrical resistance heaters sized to the same power draw as in the cooling mode of operation, thereby providing a heating capacity of approximately $\frac{2}{3}$ the cooling rating.

13-61. Boilers and Accessories

a. Types and Rating.

Type	Rating (boiler horse- power)
Vertical steel fire tube	15 25 35 60
Horizontal steel fire tube	200
Portable steel firebox	143

b. Other Data. Tables 13-59 through 13-63 give additional information on boilers and accessories.

Table 13-59. Data on Boiler Feed Pumps

Size	3 x 2 x 3	4½ x 3 x 4	5½ x 3½ x 5
Minimum capacity of pump, (gallons per minute)	6	10	25
Maximum piston speed (feet per minute)	14	20	25
Size of steam inlet (inches)	¾	¾	¾
Size of exhaust outlet (inches)	¾	2	2
Size of water suction (inches)	2	2	2
Size of water discharge (inches)	¾	¾	2
Weight, crated for export (pounds)	350	400	600
Cubage, crated for export (cubic feet)	5	7	10

Table 13-60. Data on Feed-Water Heaters

Coil surface (sq. ft.) minimum	20	30	75
Condensing capacity (pounds per hour)	100	160	400
Water flow (gallons per minute) minimum	6	10	25
Steam-supply connection (inches)	¾	2	2
Condensate connection (inches)	¾	¾	¾
Water inlet and outlet (inches)	¾	¾	22
Safety valve (inches)	¾	¾	1½
Connections to oil separator (inches)	¾	¾	2
Grease trap, inlet and outlet (inches)	¾	¾	¾
Float and thermostatic trap inlet and outlet (inches)	¾	¾	¾
Weight, crated for export (pounds)	225	250	325
Cubage, crated for export (cubic feet)	9	11	13

Table 13-61. Data on Surge Tanks

Capacity (gal)	72	145	185
Tank dimensions	24 by 42	24 by 72	30 by 60
Installed position	Horizontal	Horizontal	Vertical
Condensate return connection (inches)	2	2	2
Feed-water connection (inches)	¾	¾	¾
Vent connection (inches)	2	2	2
Pump suction connection (inches)	2	2	2

Table 13-61. Data on Surge Tanks—Continued

Capacity (gal)	72	145	185
Drain connection (inches) -----	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
Weight, crated for export (pounds) -----	560	800	900
Cubage, crated for export (cubic feet) -----	18	25	30

Table 13-62. Data on Storage Type Hot-Water Generators

Storage capacity (gal)	750	365	220
Diameter of shell (inches) -----	48	36	30
Length of shell (inches) -----	96	84	72
Shell thickness (inches) minimum -----	0.312	0.250	0.187
Coil heating surface (square feet) minimum -----	33	10	5
Tappings for hot- and cold-water connections (inches) -----	¹ 4	2	2
Tappings for steam, condensate, relief, and drain connections (inches) -----	2	2	2
Combination temperature and pressure-relief valve (capacity in British thermal units -----	1,000,000	300,000	300,000
Size of temperature regulating valve (inches) -----	1½	1	$\frac{3}{4}$
Weight, crated for export (pounds) -----	2,250	1,700	1,200
Cubage, crated for export (cubic feet) -----	112	86	60

¹ Four-inch connections are flanged with threaded cast-iron companion flanges and necessary nuts, bolts, and gaskets.

Table 13-63. Data on Boilers

Stock No.	Item
4410-277-3139	Boiler, steam, high pressure, horizontal; horsepower not rated, 400 lb. steam; forced or induced draft, oil fired.
4410-277-5871	Boiler, steam, high pressure, horizontal; 200 hp., 6,900 lb. steam; forced draft; oil fired, w/27 accessories.
4410-277-3147	Boiler, steam, high pressure, vertical; 60 hp., steam delivery not rated; induced draft, coal fired, hand, or oil fired.

13-62. Steam Generators

Table 13-64 gives logistical data on steam generators.

13-63. Utilities Requirements

Utilities required for standard buildings, (hospitals, barracks, mess halls, etc.) are grouped and listed in TM 5-303.

Table 13-64. Steam Generators

Rating pounds of steam per hour	400	200
Weight, crated for export (pounds) -----	4,000	3,000
Cubage, crated for export (cubic feet) -----	160	120
Condensate pump (gallons per minute) -----	3	1½
Condensate receiver, capacity (gallons) -----	10	10
Oil burner (gallons per hour at rated capacity) -----	4	2
Connections (inches):		
Condensate return -----	$\frac{3}{4}$	$\frac{3}{4}$
Make-up water -----	$\frac{3}{4}$	$\frac{3}{4}$
Blowoff (blowdown) -----	$\frac{3}{4}$	$\frac{3}{4}$
Steam supply -----	2	2
Motor, fan (horsepower) -----	$\frac{3}{4}$	$\frac{3}{4}$
Motor, condensate pump (horsepower) -----	$\frac{3}{4}$	$\frac{3}{4}$



CHAPTER 14

STRUCTURAL DESIGN DATA

Section I. DESIGN LOADS

14-1. Purpose

This chapter provides formulas, data, and criteria for the design of nonstandard fixed bridges, buildings, and other similar structures required for temporary use in theaters of operation, based on the use of standard or commercial construction materials. In general, information is simplified and abridged and does not cover all of the details which need to be considered for permanent structures. For more authoritative details of design, consult the references listed in this chapter and in appendix A.

14-2. Dead Loads

a. General. The weights of the elements of a structure are computed and combined as required for the design of each structural member. Utilities, such as water tanks, which are an integral part of a structure are included in dead loads. Structural members are designed using assumed values for their own weights, then redesigned if necessary.

b. Highway Bridge Floor and Stringers. Tables 14-1, 14-2, and 14-3 give dead load in pounds per linear foot of bridge, for three types of bridge.

Table 14-1. Dead Load in Pounds Per Foot of Bridge—6-Inch Timber Floor With Timber Stringers, Curb, and Railing

Class	Type	Span in feet												
		13	14	15	16	17	18	19	20	21	22	23	24	25
8 ---	Single-lane 14'-roadway ..	400	410	410	420	420	430	430	440	440	450	450	460	460
	Double-lane 24'-roadway ..	640	650	660	670	680	690	690	700	710	720	730	740	740
24 ---	Single-lane 14'-roadway ..	460	470	480	490	500	510	510	520	530	540	550	560	560
	Double-lane 24'-roadway ..	730	750	770	790	810	820	840	860	880	900	920	930	950
70 ---	Single-lane 14'-roadway ..	500	530	560	580	610	640	660	690	720	740	770	800	820
	Double-lane 24'-roadway ..	840	880	930	970	1,020	1,050	1,090	1,130	1,170	1,220	1,260	1,300	1,340

Table 14-2. Dead Load in Pounds Per Foot of Bridge—Steel Stringers With 6-Inch Timber Floor, Timber Curb, and Railing

Class	Type	Span in feet								
		20	30	40	50	60	70	80	90	100
8 -----	Single-lane 14'-roadway -----	480	520	560	600	630	670	710	750	780
	Double-lane 24'-roadway -----	770	840	900	970	1,030	1,100	1,160	1,220	1,280
24 -----	Single-lane 14'-roadway -----	570	620	660	710	750	800	840	890	930
	Double-lane 24'-roadway -----	940	1,010	1,080	1,150	1,220	1,290	1,360	1,430	1,500
70 -----	Single-lane 14'-roadway -----	650	740	830	920	1,010	1,100	1,190	1,280	1,370
	Double-lane 24'-roadway -----	1,050	1,210	1,370	1,530	1,690	1,850	2,010	2,170	2,320

Table 14-3. Dead Load in Pounds Per Foot of Bridge—Steel Stringers with 6-Inch Concrete Floor and Concrete Curb Timber Railing

Class	Type	Span in feet								
		20	30	40	50	60	70	80	90	100
8 -----	Single-lane 14'-roadway -----	1,500	1,560	1,610	1,670	1,720	1,780	1,830	1,880	1,930
	Double-lane 24'-roadway -----	2,250	2,330	2,400	2,480	2,550	2,630	2,700	2,780	2,850
24 -----	Single-lane 14'-roadway -----	1,580	1,650	1,720	1,790	1,860	1,930	2,000	2,070	2,140
	Double-lane 24'-roadway -----	2,360	2,480	2,590	2,700	2,810	2,920	3,030	3,140	3,250
70 -----	Single-lane 14'-roadway -----	1,660	1,770	1,880	1,980	2,100	2,210	2,320	2,430	2,540
	Double-lane 24'-roadway -----	2,480	2,680	2,880	3,080	3,270	3,470	3,670	3,870	4,060

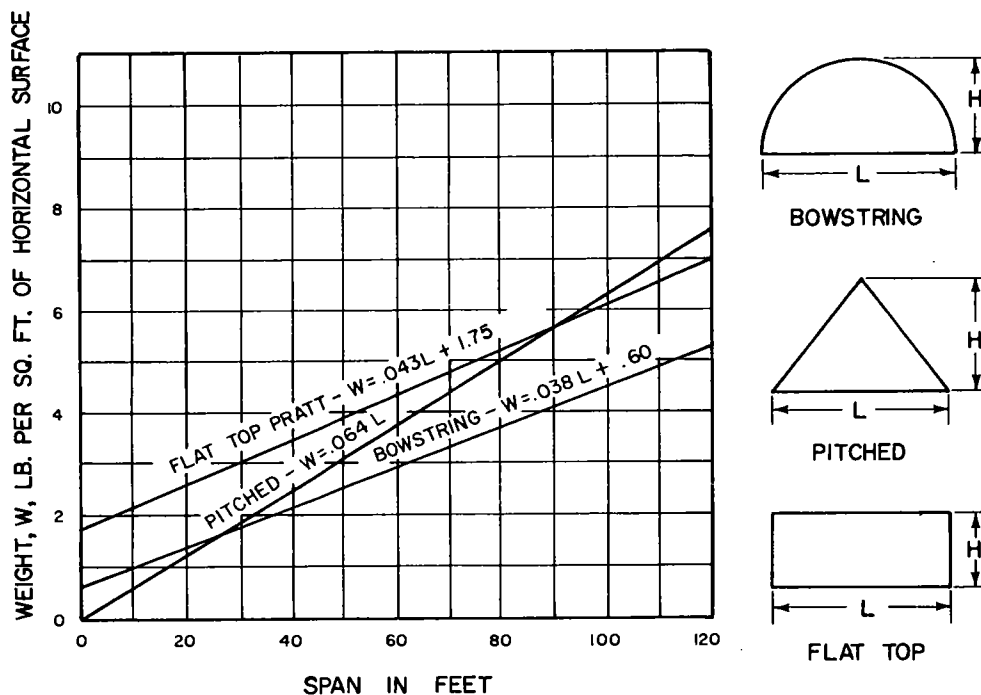


Figure 14-1. Formulas for estimating the weights of wooden trusses.

c. *Wood-Roof Trusses.* Preliminary allowances for the weight of wood-roof trusses are:

- (1) Pitched: $W = .064L$
- (2) Flat-top: $W = .043L + 1.75$
- (3) Bowstring: $W = .038L + .60$

where—

W = weight in pounds psf of horizontal projection of the area supported,
 L = span of truss in ft.
 Refer to figure 14-1 to check the initial estimate.

d. *Steel-Roof Trusses.* Preliminary estimate of weight of steel-roof truss is—

$$W = \frac{3 PL}{450 + 15L + PS}$$

where

W = psf of horizontally covered surface
 L = truss span in ft
 S = truss spacing in ft
 P = load in pounds psf of horizontally covered area carried by truss.

e. *Weight of Material.* The weights of materials given for estimating live loads in paragraph 14-3 are listed in table 14-4.

14-3. Live Loads

a. *General.* In addition to dead loads, it is necessary to consider live loads, i.e. loads that vary in

position, in designing a structure. It is convenient to classify live loads into movable loads and moving loads. Movable loads are those which may be moved from one position to another on a structure, such as the contents of a storage building. They are usually applied gradually and without impact. Moving loads are those which move under their own power, such as a railroad train or a truck. They are usually applied rapidly and with impact effect on the structure.

b. *Highway Bridges.* The live load for highway bridges consists of the applied moving load of vehicles and pedestrians. Actually, the traffic over a highway bridge will consist of a multitude of different types of vehicles. It is designed, however, for a train of standard trucks at the designated speed, interval, and number of lanes. To determine the moment and shear caused by the design class vehicle use the charts in table 14-5 and 14-6. These values are for one-lane and should be doubled for two-lane bridges.

c. *Railroad Bridges.*

(1) The live load for railroad bridges consists of the locomotives and cars that cross them. The live load for each track is usually taken as that corresponding to two locomotives followed by a uniform load which represents the weight of the cars. For military railroad bridges, axle loadings of Cooper's E-45 loading (45,000 lb

Table 14-4. Material Weights

Material ¹	Weight of material per cu ft of space (pounds)	Height of pile (feet)	Weight per sq ft of floor (pounds)	Recommended live load (pounds per square foot)
Building materials:				
Bricks	45	6	270	300
Portland cement	72 to 105	6	432 to 630	to
Lumber	45	6	270	400
Painting materials:				
Linseed oil in drums	45	4	180	200 to
White lead paste in cans	174	3½	610	300
Dry goods:				
Cotton sheeting, in cases	23	8	184	200 to
Wool, in bales, compressed	48			250
Groceries:				
Canned goods in cases	58	6	348	250
Coffee, roasted, in bags	33	8	264	to
Sugar, in cases	51	6	306	300
Hardware:				
Chain	100	6	600	300
Wire, insulated copper, in coils	63	5	315	to
Wire, galvanized iron, in coils	74	4½	333	400
Miscellaneous:				
Tires	30	6	180	
Books (solidly packed)	65	6	390	
Paper (newspapers)	35	6	210	
Rope, in coils	32	6	192	
Rubber, crude	50	8	400	
Chinaware, in crates	40	8	320	

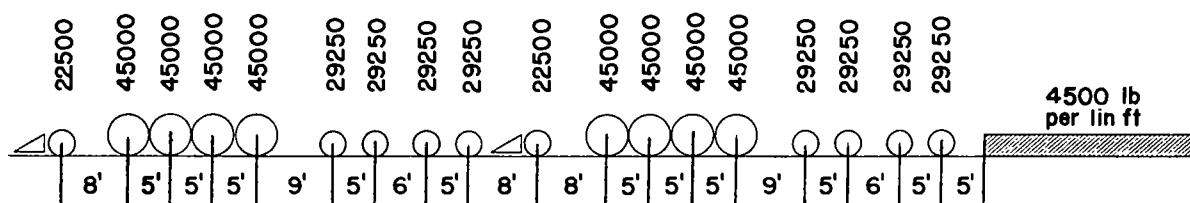
¹ See table B-14 also.

Figure 14-2. Cooper's E-45 loading.

per axle) (fig 14-2) are used in design. The moments, shears, and pier reactions produced by this loading, for each rail, are tabulated in table 14-7.

(2) Cooper's E-45 loading produces for each rail the moments, shears, and pier reactions shown in table 14-7. The values for any other Cooper's loading are directly proportional to those tabulated for Cooper's E-45: e.g., for E-30, multiply the tabulated values by 30/45. The values are adjusted for dead loads, wind loads, and impact loads.

(3) For a more detailed and complete design criteria of military railroad bridges, refer to TM 5-370.

d. Building.

(1) *Uniformly distributed loads.* Live loads for buildings are usually considered as movable distributed loads of uniform intensity. Table 14-8 lists the minimum design of uniformly distributed loads of common structures. For a more complete list refer to TM 5-808-1.

(2) *Concentrated loads.* Floors must be designed to support the uniformly distributed live loads or the concentrated load given in table 14-8, whichever produces the greatest stress. Unless otherwise specified the indicated concentration is assumed to occupy an area of 2½ feet square and is so located as to produce the maximum stress conditions in the structural members.



(Located in back of manual.)

*Table 14-5. Wheeled and Tracked Vehicle Bending Moment in Kip-Feet
(4-100 ft Spans)*



Table 14-6. Wheeled and Tracked Vehicle Shear in Short Tons (4-100 ft Spans)

(Located in back of manual.)

Table 14-7. Moments, Shears, Pier Reactions for Cooper's E-45 Loading

Span (feet)	Maximum moment (M) (kips- foot)	Maximum shear (V)			Maximum pier reaction (R) (kips)	Equivalent uniform load		
		End (kips)	Quarter- point (kips)	Center (kips)		For maximum moment (pound- foot)	For maximum end shear (pound- foot)	For maximum pier reaction (pound- foot)
10	63.4	33.8	22.5	11.3	45.0	5,063	6,750	4,500
11	73.0	36.8	23.5	12.2	49.1	4,887	6,705	4,464
12	90.0	39.4	24.4	13.1	52.6	5,004	6,561	4,374
13	106.9	41.6	25.1	13.0	55.4	5,063	6,390	4,266
14	123.8	43.4	26.6	14.6	58.7	5,049	6,210	4,194
15	140.7	45.0	28.2	14.9	61.5	5,004	6,003	4,100
16	157.5	57.8	29.6	15.4	64.0	4,923	5,976	4,001
17	174.4	50.3	30.9	15.6	66.2	4,824	5,922	3,893
18	191.3	52.5	31.9	15.7	68.3	4,725	5,841	3,789
19	210.0	54.5	32.9	15.8	70.7	4,653	5,733	3,726
20	233.0	56.3	33.8	15.8	73.7	4,644	5,625	3,670
21	254.3	57.8	35.3	16.3	76.4	4,590	5,613	3,636
22	276.4	59.3	36.8	16.9	79.8	4,545	5,391	3,582
23	298.6	60.7	38.2	17.4	81.2	4,500	5,274	3,528
24	320.9	62.4	39.4	17.8	83.2	4,446	5,198	3,465
25	343.2	63.9	40.5	18.2	85.1	4,392	5,112	3,402
26	365.4	65.3	41.5	18.5	87.4	4,338	5,027	3,362
27	387.7	66.6	42.5	19.0	90.1	4,375	4,932	3,339
28	411.2	68.0	43.4	19.3	92.5	4,221	4,851	3,303
29	436.5	69.2	44.2	19.6	94.9	4,163	4,770	3,272
30	461.7	70.9	45.0	19.9	97.1	4,104	4,730	3,236
31	487.0	72.5	45.8	20.4	99.5	4,050	4,676	3,213
32	512.4	73.9	46.6	21.1	102.3	4,005	4,617	3,200
33	537.7	75.3	47.3	21.6	105.0	3,951	4,563	3,182
34	563.2	76.6	48.2	22.1	107.5	3,897	4,505	3,159
35	588.4	77.9	49.0	22.6	109.8	3,848	4,451	3,137
36	617.2	79.4	49.6	23.2	112.0	3,816	4,410	3,110
37	646.1	80.8	50.4	23.6	114.2	3,780	4,370	3,087
38	675.0	82.3	51.0	23.9	116.7	3,753	4,329	3,069
39	705.0	83.6	51.8	24.4	119.1	3,721	4,288	3,051
40	737.2	84.9	52.7	24.8	121.5	3,690	4,244	3,038
42	802.8	87.8	54.2	25.5	126.2	3,636	4,185	3,006
44	868.1	90.6	55.7	26.1	131.0	3,582	4,122	2,979
46	933.6	93.2	57.1	26.6	135.8	3,537	4,050	2,952
48	998.6	95.7	58.6	27.2	140.4	3,483	3,987	2,925
50	1,069.7	98.1	60.1	28.0	144.9	3,429	3,924	2,898
55	1,256.5	104.2	62.9	29.7	157.9	3,339	3,794	2,876
60	1,462.1	110.3	67.7	31.4	172.4	3,249	3,672	2,876
65	1,684.7	116.7	70.9	33.1	18.6	3,195	3,591	2,862
70	1,921.0	124.3	74.2	34.6	199.2	3,137	3,551	2,844
75	2,166.6	132.4	77.1	36.4	211.7	3,087	3,528	2,822
80	2,432.5	139.8	80.6	37.9	223.7	3,038	3,497	2,799
85	2,707.7	147.1	84.5	39.7	234.7	3,002	3,465	2,763
90	3,004.3	154.4	88.6	41.3	245.9	2,966	3,429	2,732
95	3,306.9	161.6	92.8	42.8	256.6	2,934	3,402	2,700
100	3,622.4	168.8	97.4	44.3	266.9	2,898	3,375	2,669
105	3,979.8	175.6	101.4	45.6	276.8	2,894	3,334	2,637
110	4,372.7	182.3	105.6	47.1	286.7	2,889	3,312	2,606
115	4,775.6	188.9	109.7	48.5	296.1	2,889	3,285	2,574
120	5,190.8	195.4	113.8	50.0	306.0	2,885	3,258	2,552
125	5,621.0	201.8	127.8	51.8	316.1	2,880	3,231	2,529
150	7,945.1	233.3	137.0	61.2	366.0	2,826	3,110	2,439
175	10,521.5	263.8	155.6	70.4	418.1	2,750	3,015	2,390
200	13,357.1	293.7	172.6	79.2	471.4	2,669	2,939	2,358
250	19,791.5	362.4	206.6	95.7	579.6	2,534	2,817	2,318

Table 14-8. Uniformly Distributed Loads

Use or occupancy	Live load in psf
Barracks	40
Hospital operating rooms	60
Hospital wards	40
Offices	80
Messhalls	100
Gymnasium and assembly rooms	100
Reviewing stands and bleachers	100
Warehouses, light storage	125
Warehouses, heavy storage	250
Concentrated loads	
Office floor	2000
Stair treads (on center of tread)	300
Sidewalks	8000

(3) *Partition loads.* In buildings designed for live loads less than 100 psf, an assumed partition load of 300 pounds per linear foot of masonry partition, or the actual computed partition load, if greater, is used in the design. For permanent or semipermanent buildings not initially divided by partitions, allowance is made in live loads on this basis for future partitions.

e. Live Load Reduction.

(1) No live load reductions are made in roof members nor in buildings used for assembly purposes.

(2) In other buildings designed for live loads of 100 pounds or less per square foot, the design live load on any member carrying 150 square feet or more may be reduced at the rate of 0.08 percent per square foot of area supported by the member. The reduction shall not exceed 60 percent nor shall it exceed R as determined by the following formula:

$$R = 100 \times \frac{D + L}{4.33 L}$$

R = Reduction in percent

D = Dead load psf of area supported by the member

L = Design live load psf of area supported by the member

(3) In buildings designed for live loads of more than 100 pounds psf, no reductions are made except that live loads on columns may be reduced 20 percent.

14-4. Roof Live Loads

a. Flat, Pitched, or Curved Roofs. Ordinary roofs, either flat, pitched, or curved, shall be de-

signed for a load not less than 20 psf of horizontal projection in addition to the dead load, and in addition to either the wind or the earthquake load, whichever produces the greater stresses. See figure 14-3 for the minimum roof live load in the United States.

b. Special Conditions. When the effect of the shape of roof structure indicates greater snow-retention value, such as valleys formed by multiple series of roofs, the roof load shall be increased as deemed appropriate. For roofs pitched more than 15 degrees, reduction of live load design by $\frac{1}{3}$ pound per degree of pitch is allowed.

14-5. Wind Loads

a. General. Wind loads are of significant importance in the design of large structures such as tall buildings, towers, and long-span bridges, and for structures, such as warehouses and hangars, having large open interiors and walls in which large openings may occur. In design, wind pressure is assumed to be a steady force, although in reality it is variable pulsating force with gust effects. The wind load is dependent on the conditions of the expected maximum wind velocity according to the geographical location and the exposure and shape of the structure. For most locations in the United States a design to withstand a wind velocity of 100 mph is satisfactory. For more specific information refer to TM 5-809-1.

b. Bridges. Short bridges (100 feet or less) usually are designed with no allowance for wind. For bridges of 100 feet or more, the following wind loads are used in design.

(1) With no live load on bridge, 30 psf on 1.5 times the net area of the side elevation.

(2) With full live load, 15 psf on 1.5 times the net area of bridge and load, and increase the allowable live load stress by 5 percent.

(3) A horizontal wind force, acting against vehicles on the bridge, equal to 200 pounds per linear foot, should be assumed at a height of 6 feet above the roadway.

c. Buildings. The wind pressure and suction loads normally used in design, in psf of vertical projection, are given in table 14-9. Wind pressure and suction both act in a direction normal to the plane of a roof or wall.

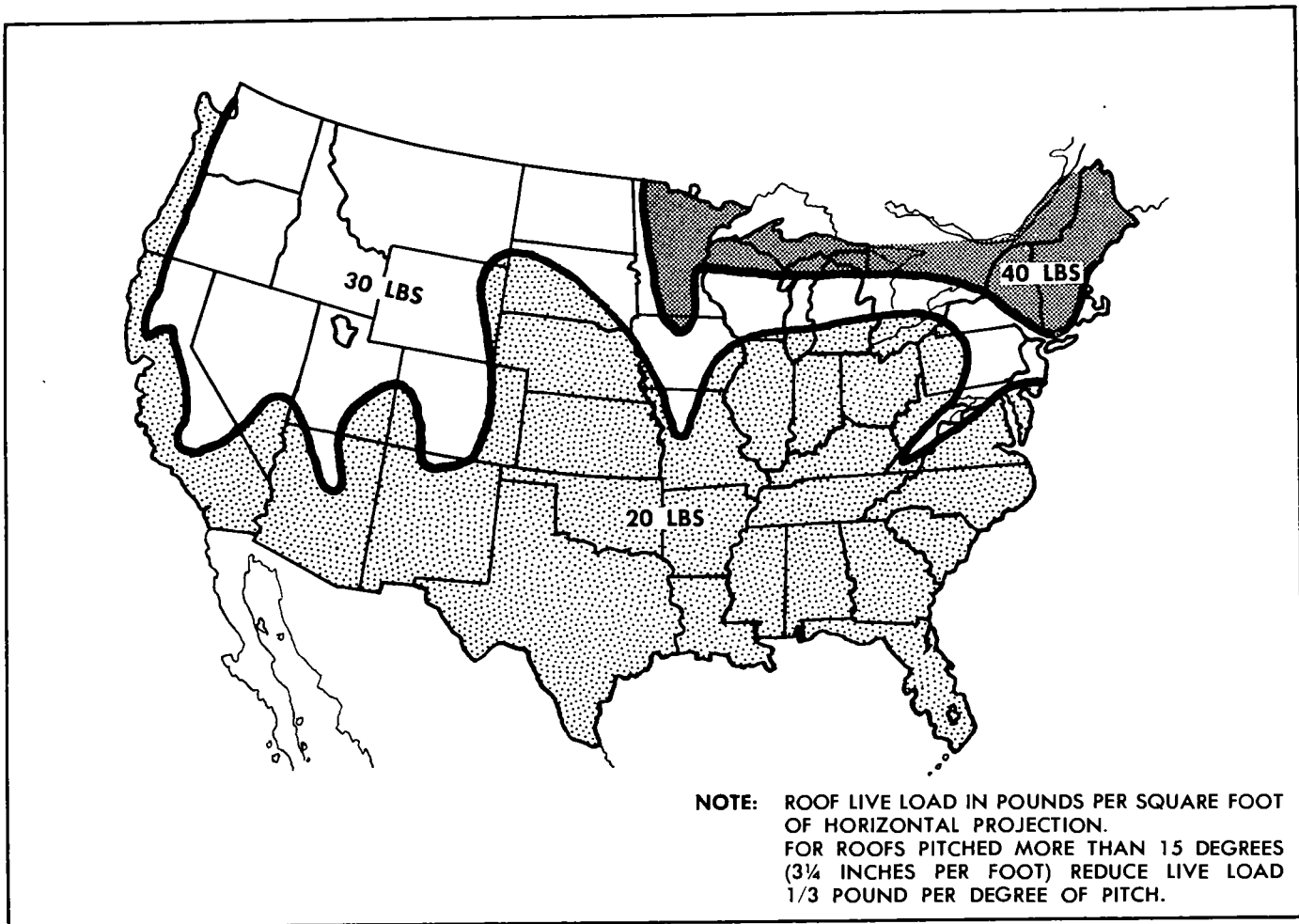


Figure 14-3. Roof live loads in the United States.

14-6. Snow and Ice Loads

a. Snow loads are of importance in northern regions, particularly in the design of roofs. The depth of snow that will gather on a roof will depend on the slope of the roof and on the roughness of the roof surface. The value of 20 psf on the projected area is considered a minimum in the areas where snowfall is expected. Where loads exceed 20 psf the excess may be reduced from its full value at a 20° slope to zero at a 60° slope.

b. Ice loads may also be of some importance, as, for example, in designing a tower built up of relatively small members which have proportionately large areas on which ice may gather. Ice having a density equal approximately to that of water may build up to a thickness of 2 inches or more on such members.

14-7. Other Live Loads

a. Lateral Loads. In addition to wind loads there are certain other loads that are almost always applied horizontally and that must be considered in structural design. Such loads, called lateral loads, are caused by soil pressures, hydrostatic pressures, forces due to earthquakes, centrifugal forces, and longitudinal forces.

b. Soil Pressures. Loads on retaining walls, on walls of buildings and on other structures due to the pressure of soil must frequently be considered in a design. The lateral pressure caused by soil on a wall varies when the wall yields. After an adequate small movement of the wall, the soil pressure reaches a minimum known as the "active pressure." If the wall is forced into the backfill, the pressure between the wall and

Table 14-9. Wind Pressures on Buildings

	Surface			Load in pounds per square foot of vertical projection	
				Pressure	Suction
Exterior walls	Temporary buildings not used for assembly			10	
	Permanent buildings			20	
Additional load on interior side of exterior walls.	Buildings nominally tight			4.5 or	4.5
	Buildings between tight and 30 percent open			4.5 to ¹ 12 or	4.5 to ¹ 19
	Buildings 30 percent or more open			12 or	19
Chimneys	Square or rectangular			30	
	Hexagonal or octagonal			24	
	Round or elliptical			18	
Flat roofs					12
Pitched roofs	Windward side	Roofs pitched under 20°			12
		Roofs pitched 20° to 30°			12
		Roofs pitched 30° to 60°		0 to ¹ 9	12 to ¹ 0
		Roofs pitched 60° and over		9	
	Leeward side, all pitches				9
	Bowstring roofs.	Starting at ground level.	Windard $\frac{1}{4}$ of arc	Ratio— Rise: Run 0.0 to 0.6	Pressure 0 to ¹ 11.4	Suction
Central $\frac{1}{2}$ of arc			any		11
Leeward $\frac{1}{4}$ of arc			any		9
On elevated Supports.		Windward $\frac{1}{4}$ arc	$\left\{ \begin{array}{l} 0.0 \text{ to } 0.2 \\ 0.2 \text{ to } 0.6 \\ 0.2 \text{ to } 0.35 \end{array} \right.$	0 to ¹ 12 (or)	12
		Central $\frac{1}{2}$ of arc	0.0 to 0.6		12 to ¹ 0
		Leeward $\frac{1}{4}$ of arc	any		11 to ¹ 20
					9

¹ Uniform rate of increase or decrease.

the backfill increases to a maximum known as the "passive pressure." Under usual conditions the active pressure at any depth is about $\frac{1}{4}$ the vertical pressure, and the passive pressure is about 4 times the vertical pressure, where the vertical pressure is defined as $P = ph$.

P = vertical pressure at a given depth

p = density of soil

h = depth

For a more detailed and complete analysis of soil pressure refer to chapter 2, TM 5-330.

c. Hydrostatic Pressures. Dams, tanks, etc., are subjected to hydrostatic loads that are computed in accordance with the principles of hydraulics.

d. Earthquake Forces. During an earthquake, structural damage may result from the fact that the foundation of the structure undergoes acceleration. Such accelerations are largely horizontal, and vertical components of acceleration are usually neglected. The rate of horizontal acceleration is approximately one-tenth of the acceleration due to gravity. If the structure is assumed to be rigid, it will accelerate horizontally at the same rate as its foundation. Hence each part of the structure will be acted upon by a horizontal vertical force equal to its mass multiplied by acceleration, or—

$$\begin{aligned} \text{Lateral force} &= \text{mass} \times \text{acceleration} = \\ &= \frac{\text{Weight}}{g} \times 0.1g \\ &= .1 (\text{Weight}) \end{aligned}$$

Actually, the structure will undergo elastic deformations that will affect the acceleration of its various members. For more detailed information on this subject refer to TM 5-809-1.

e. Centrifugal Forces. In designing a bridge on which the tracks or roadway are curved, vehicles crossing the structure exert centrifugal force that may be of sufficient magnitude to require consideration in design. Centrifugal force may be found as follows:

$$C = \frac{W}{g} \cdot \frac{V^2}{R}$$

C = Centrifugal Force

W = Weight that travels around the curve

V = the velocity that weight W travels

R = radius of curvature

g = gravity

f. Longitudinal Forces. For a bridge longitudinal forces are applied whenever the vehicles crossing increase or decrease their speed.

(1) For railway bridges, longitudinal forces are assumed to act 6 feet above the top of the rail and that such forces shall be considered as being applied by the live load on one

track only. Longitudinal forces are taken as the larger of the following: (a) due to braking, 15 percent of the total live load, without impact, or (b) due to traction, 25 percent of the weight on the driving wheels of the locomotive, without impact.

(2) For highway bridges, longitudinal forces of 5 percent of the live load on the structure, acting 4 feet above the roadway, must be taken into consideration in a design.

14-8. Impact Loads

a. The increase in load due to sudden application of live load, over and above the value that this live load would have if it were applied gradually, is known as impact load. Impact loads are usually associated with moving live loads.

b. No allowance for impact is usually required for wooden structures, because timber is much stronger in resisting loads of short duration than in resisting permanently applied loads. For structures designed to carry heavy moving loads, live loads are modified as follows:

(1) *Highway bridges.* For steel superstructures increase the live load by 15 percent or by the fraction

$$I = \frac{50}{L + 125}$$

Where L = length in feet of the portion of the span loaded to produce the maximum stress in the member considered and I = impact fraction by which the live load is increased.

(2) *Railroad bridges.* Impact loads caused

by moving locomotives and cars are divided into two parts—the rolling effect and the direct vertical effect. The rolling effect is assumed to increase the load on one rail by 20 percent and to decrease the load on the other by 20 percent. The direct vertical effect is, for steam locomotives:

(a) For beams, stringers, girders, and floor beams,

$$I = 60 - \frac{L^2}{500} \text{ for } L \text{ less than } 100 \text{ ft.}$$

$$I = \frac{1800}{L-40} \times 10 \text{ for } L \text{ more than } 100 \text{ ft.}$$

(b) For truss spans,

$$I = \frac{4000}{L + 25} + 15$$

For electric locomotives:

$$I = 40 - \frac{3L^2}{1600} \text{ for } L \text{ less than } 80 \text{ ft.}$$

$$I = \frac{600}{L-30} + 16 \text{ for } L \text{ more than } 80 \text{ ft.}$$

Where L = length, in feet, center to center of supports of stringers, longitudinal girders, and trusses.

14-9. Combined Loads

Structures are designed for combinations of dead, live, and other loads given above, at working stresses authorized for the materials used. For combined loads, working stresses for certain materials, e.g., steel, are increased to higher values authorized under specified conditions. For steel, refer to paragraph 14-14.

Section II. DESIGN FORMULAS

14-10. Definitions

a. Stress is the force per unit area on a material.

b. Ultimate stress is the greatest stress which can be produced in a body before rupture occurs.

c. Allowable stress is the maximum stress permitted in a material.

d. Elastic limit is the maximum stress to which a material may be subjected without permanent set (plastic deformation) remaining.

e. Yield point is the stress at which a material first exhibits an appreciable increase in strain with no increase in stress.

f. Strain is the deformation of a material due to stress per unit length.

g. Modulus of elasticity is the ratio of stress to the strain, for stresses below the elastic limit.

h. Shear at any section of a beam is equal to the algebraic sum of all vertical forces on one side of the section.

i. Bending moment at any section of a beam is equal to the algebraic sum of the moments, about the center of gravity of the section, of all the forces on one side of the section.

j. Neutral plane of a beam is the plane which undergoes no change in length due to the bending and along which the direct stress is zero.

k. Neutral axis at any section of a beam is the line formed by the intersection of the neutral plane and the section.

l. Section modulus (S) of a section of a beam with I moment of inertia and c distance from neutral axis to extreme outer fiber, $S = \frac{I}{c}$.

m. Moment of inertia (I) of a body about an axis is the sum of the products of the component weights into the squares of their distance from the axis, $I = \sum wr^2$.

14-11. Factor of Safety

The factor of safety provided in a structure is usually considered to be the number of times the load might be increased before the structure would collapse due to stress. Some consider the factor of safety to be based upon ultimate strength, while others feel that the ratio of the elastic limit to the working stress is the factor of safety. In the design of a military structure the factor of safety should be maintained as high as possible with due considerations for the mission, time, cost, and material availability.

14-12. General Formulas

a. List of Symbols.

A	area
b	breadth or width
C	compression
c	distance from neutral axis to extreme fiber
d	depth, in inches
E	modulus of elasticity
e	eccentricity
F	force
f	flexural unit stress
fps	feet per second
ft-lb	foot-pound
g	acceleration due to gravity
H	horizontal shear force
h	height, depth of beam
I	moment of inertia of a body
in	inch or inches
kip	kilopound (1000 pounds)
M	moment
n	ratio of elastic moduli
P	concentrated load
p	pressure per unit area
R	radius, reaction of force
r	radius of gyration, perpendicular distance to a plane or an axis
S	section modulus
s	shear stress
sec	second
sq	square
sq ft	square feet

T	tension, torque, temperature
t	thickness
V	vertical shear force
W	weight
w	load per unit length
X	horizontal axis
x	distance parallel to x-axis
Y	vertical axis
y	distance parallel to y-axis

b. *Properties of Sections.* Areas, moments of inertia and other properties of selected geometrical shapes are given in figure 14-4.

c. Beam Formulas.

(1) Flexural stress at extreme fiber.

$$f = \frac{Mc}{I} = \frac{M}{S}$$

Graphical representation of stress distribution in a beam is in figure 14-5.

(2) Shear stress in beams.

(a) Rectangular beams.

$$s_s = \frac{3}{2} \frac{V}{A}$$

s_s = horizontal shear stress
V = total vertical shear
A = area of the section

(b) Beams of circular section.

$$s = \frac{16}{3} \frac{V}{\pi d^2}$$

(c) Steel I beams.

$$f_n = \frac{V}{\text{web thickness} \times \text{depth between curved fillets}}$$

(3) Reactions, moments, and shears for statically loaded beams and continuous beams are given in figures 14-5 and 14-6. Figure 14-7 gives diagrams and formulas for beams carrying various concentrated moving loads.

d. Column Formulas.

(1) With ends rounded:

$$\frac{P}{A} = \frac{\pi^2 E}{\left(\frac{L}{r}\right)^2}$$

(2) With ends fixed:

$$\frac{P}{A} = \frac{4\pi^2 E}{\left(\frac{L}{r}\right)^2}$$

(3) With one end fixed and one end rounded:

$$\frac{P}{A} = \frac{9}{4} \frac{\pi^2 E}{\left(\frac{L}{r}\right)^2}$$

where: L = length of column
r = radius of gyration
and $\frac{L}{r}$ = slenderness ratio

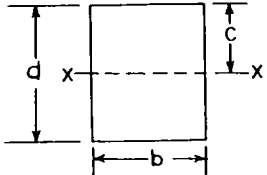
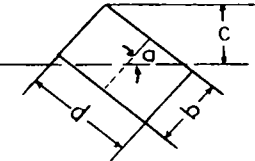
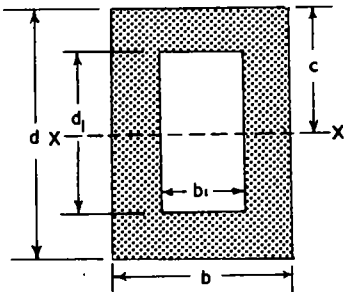
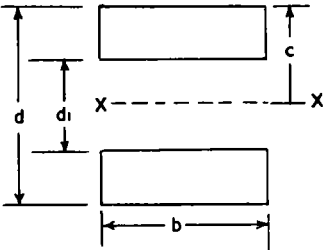
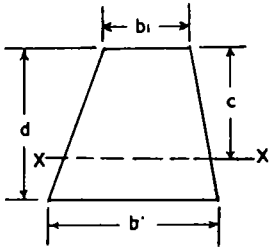
Rectangle Axis of moments through center 	$A = bd$ $c = \frac{d}{2}$ $I = \frac{bd^3}{12} \quad f_h = \frac{3}{2} \frac{V}{bd}$ $S = \frac{bd^2}{6}$ $r = \frac{d}{\sqrt{12}} = .288675 d$
Rectangle Axis of moments only line through center of gravity 	$A = bd$ $c = \frac{b \sin \alpha + d \cos \alpha}{2}$ $I = \frac{bd (b^2 \sin^2 \alpha + d^2 \cos^2 \alpha)}{12}$ $S = \frac{bd (b^2 \sin^2 \alpha + d^2 \cos^2 \alpha)}{6 (b \sin \alpha + d \cos \alpha)}$ $r = \sqrt{\frac{b^2 \sin^2 \alpha + d^2 \cos^2 \alpha}{12}}$
Hollow Rectangle Axis of moments through center 	$A = bd - b_1 d_1$ $c = \frac{d}{2}$ $I = \frac{bd^3 - b_1 d_1^3}{12}$ $S = \frac{bd^2 - b_1 d_1^2}{6d}$ $r = \sqrt{\frac{bd^3 - b_1 d_1^3}{12A}}$
Equal Rectangles Axis through center of gravity 	$A = b (d - d_1)$ $c = \frac{d}{2}$ $I = \frac{b (d^3 - d_1^3)}{12}$ $S = \frac{b (d^3 - d_1^3)}{6d}$ $r = \sqrt{\frac{d^3 - d_1^3}{12 (d - d_1)}}$
Trapezoid Axis of moments through center of gravity 	$A = \frac{d (b + b_1)}{2}$ $c = \frac{d (2b + b_1)}{3 (b + b_1)}$ $I = \frac{d^3 (b^2 + 4bb_1 + b_1^2)}{36 (b + b_1)}$ $S = \frac{d^2 (b^2 + 4bb_1 + b_1^2)}{12 (2b + b_1)}$ $r = \frac{d}{6 (b + b_1)} \sqrt{2 (b^2 + 4bb_1 + b_1^2)}$

Figure 14-4. Properties of sections.

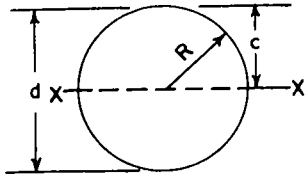
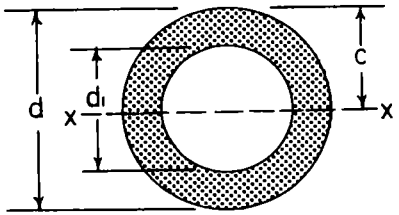
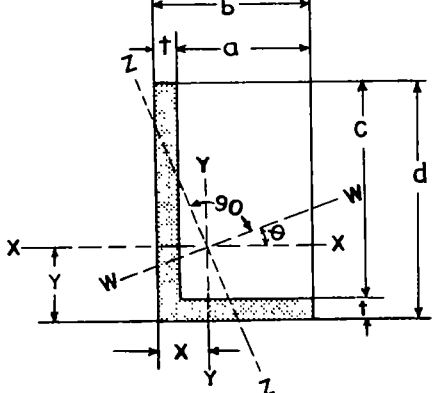
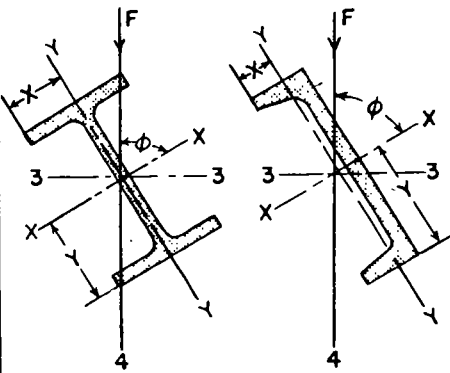
Circle Axis through center 	$A = \frac{\pi d^2}{4} = \pi R^2 = .785398 d^2 = 3.141593 R^2$ $c = \frac{d}{2} = R$ $I = \frac{\pi d^4}{64} = \frac{\pi R^4}{4} = .049087 d^4 = .785398 R^4$ $S = \frac{\pi d^3}{32} = \frac{\pi R^3}{4} = .098175 d^3 = .785398 R^3$ $r = \frac{d}{4} = \frac{R}{2} \qquad f_b = \frac{16V}{3\pi d^2}$
Hollow Circle Axis through center 	$A = \frac{\pi(d^2 - d_1^2)}{4} = .785398 (d^2 - d_1^2)$ $c = \frac{d}{2}$ $I = \frac{\pi(d^4 - d_1^4)}{64} = .049087 (d^4 - d_1^4)$ $S = \frac{\pi(d^4 - d_1^4)}{32d} = .098175 \frac{d^4 - d_1^4}{d}$ $r = \frac{\sqrt{d^2 + d_1^2}}{4}$
Angle Axis through center of gravity 	$A = t(b + c) \quad x = \frac{b^2 + ct}{2(b + c)} \quad y = \frac{d^2 + ct}{2(b + c)}$ $I_x = \frac{1}{3} [t(d-y)^3 + by^3 - a(y-t)^3]$ $I_y = \frac{1}{3} [t(b-x)^3 + dx^3 - c(x-t)^3]$ $I_z = I_x \sin^2 \theta + I_y \cos^2 \theta + K \sin 2\theta$ $I_w = I_x \cos^2 \theta + I_y \sin^2 \theta - K \sin 2\theta$ $K = \frac{abcdt}{4(b + c)} \quad K \text{ is negative when heel of angle, with reference to c. g., is in 1st or 3rd quadrant, positive when in 2d or 4th.}$
Beams and Channels Transverse force oblique through c. g. 	$I_a = I_x \sin^2 \phi + I_y \cos^2 \phi$ $I_b = I_x \cos^2 \phi + I_y \sin^2 \phi$ $f = M \left(\frac{y}{I_x} \sin \phi + \frac{x}{I_y} \cos \phi \right)$ Where M is bending moment due to force F

Figure 14-4—Continued.

Simple beam, concentrated load at any point

Equivalent uniformly distributed load

$$= \frac{8Pob}{l^2}$$

 $R_1 = V_1$ (max when $a < b$)

$$= \frac{Pb}{l}$$

 $R_2 = V_2$ (max when $a > b$)

$$= \frac{Pa}{l}$$

 $M_{\max}$ (at point of load)

$$= \frac{Pab}{l}$$

 M_x (when $x < a$)

$$= \frac{Pbx}{l}$$

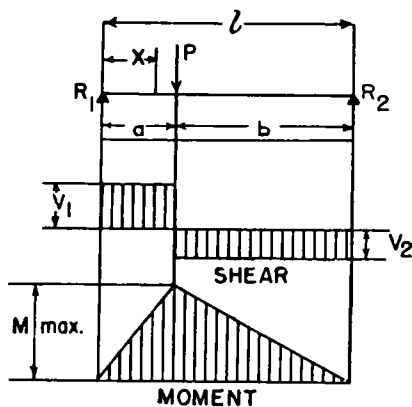
$$\Delta_{\max} \text{ (at } x = \sqrt{\frac{a(o+2b)}{3}} \text{ when } a > b) = \frac{Pab(o+2b)}{27EI} \sqrt{3o(a+2b)}$$

 Δ_o (at point of load)

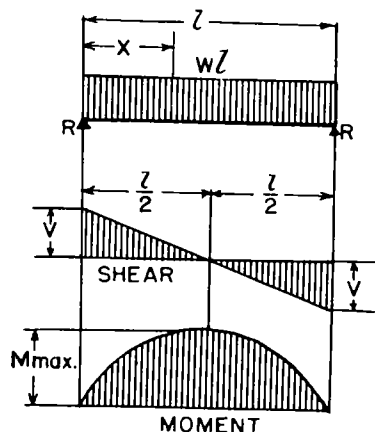
$$= \frac{Pa^2b^2}{3EI}$$

 Δ_x (when $x < a$)

$$= \frac{Pbx}{6EI} (l^2 - b^2 - x^2)$$



Simple beam, uniformly distributed load.

Equivalent uniformly distributed load = wl $R = V$

$$= \frac{wl}{2}$$

 V_x

$$= w \left(\frac{l}{2} - x \right)$$

 $M_{\max}$ (at center)

$$= \frac{wl^2}{8}$$

 M_x

$$= \frac{wx}{2} (l - x)$$

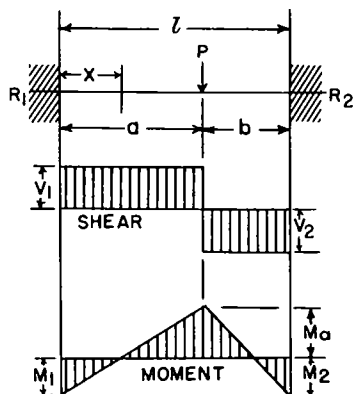
 $\Delta_{\max}$ (at center)

$$= \frac{5wl^4}{384EI}$$

 Δ_x

$$= \frac{wx}{24EI} (l^3 - 2lx^2 + x^3)$$

Beam fixed at both ends, concentrated load at any point.



$$R_1 = V_1 \text{ (max when } a < b) = \frac{Pb^2}{l^2} (3a + b)$$

$$R_2 = V_2 \text{ (max when } a > b) = \frac{Pa^2}{l^2} (a + 3b)$$

$$M_1 \text{ (max when } a < b) = \frac{Pab^2}{l^2}$$

$$M_2 \text{ (max when } a > b) = \frac{Pa^2b}{l^2}$$

$$M_a \text{ (at point of load)} = \frac{2Pa^2b^2}{l^3}$$

$$M_x \text{ (when } x < a) = R_1x - \frac{Pbx^2}{l^2}$$

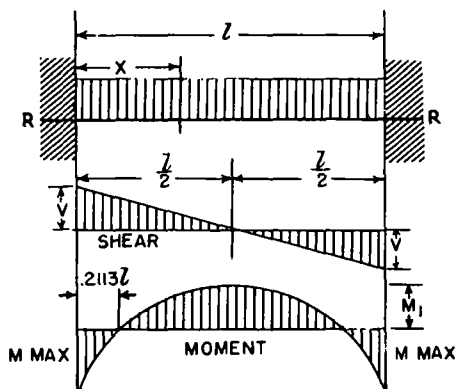
$$\Delta_{\max} \text{ (when } a > b \text{ at } x = \frac{2a}{3a+b}) = \frac{2Pa^3b^2}{3EI(3a+b)^2}$$

$$\Delta_a \text{ (at point of load)} = \frac{Pa^3b^3}{3EI}$$

$$\Delta_x \text{ (when } x < a) = \frac{Pbx^3}{6EI} (3a - 3ax - bx)$$

Beam fixed at both ends, uniformly distributed load.

$$\text{Equivalent uniform load (as a simple beam)} = \frac{2wl}{3}$$



$$R = V = \frac{wl}{2}$$

$$V_x = w \left(\frac{l}{2} - x \right)$$

$$M_{\text{max}} \text{ (at ends)} = \frac{wl^2}{12}$$

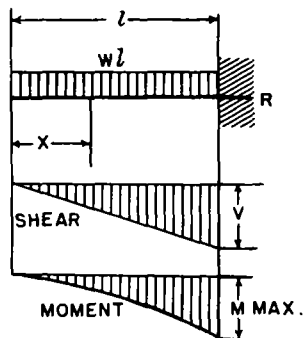
$$M_1 \text{ (at center)} = \frac{wl^2}{24}$$

$$M_x = \frac{w}{12} (6lx - l^2 - 6x^2)$$

$$\Delta_{\text{max}} \text{ (at center)} = \frac{wl^4}{384EI}$$

$$\Delta_x = \frac{wx^2}{24EI} (l - x)^2$$

Cantilever beam, uniformly distributed load.



$$\text{Equivalent uniform load (as a simple beam)} = 4wl$$

$$R = V = wl$$

$$V_x = wx$$

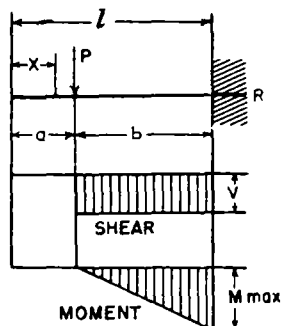
$$M_{\text{max}} \text{ (at fixed end)} = \frac{wl^2}{2}$$

$$M_x = \frac{wx^2}{2}$$

$$\Delta_{\text{max}} \text{ (at free end)} = \frac{wl^4}{8EI}$$

$$\Delta_x = \frac{w}{24EI} (x^4 - 4l^3x + 3l^4)$$

Cantilever beam, concentrated load at any point



$$\text{Equivalent uniform load (as a simple beam)} = \frac{3Pb}{l}$$

$$R = V \text{ (when } x < a) = P$$

$$M_{\text{max}} \text{ (at fixed end)} = Pb$$

$$M_x \text{ (when } x > a) = P(x - a)$$

$$\Delta_{\text{max}} \text{ (at free end)} = \frac{Pb^2}{6EI} (3l - b)$$

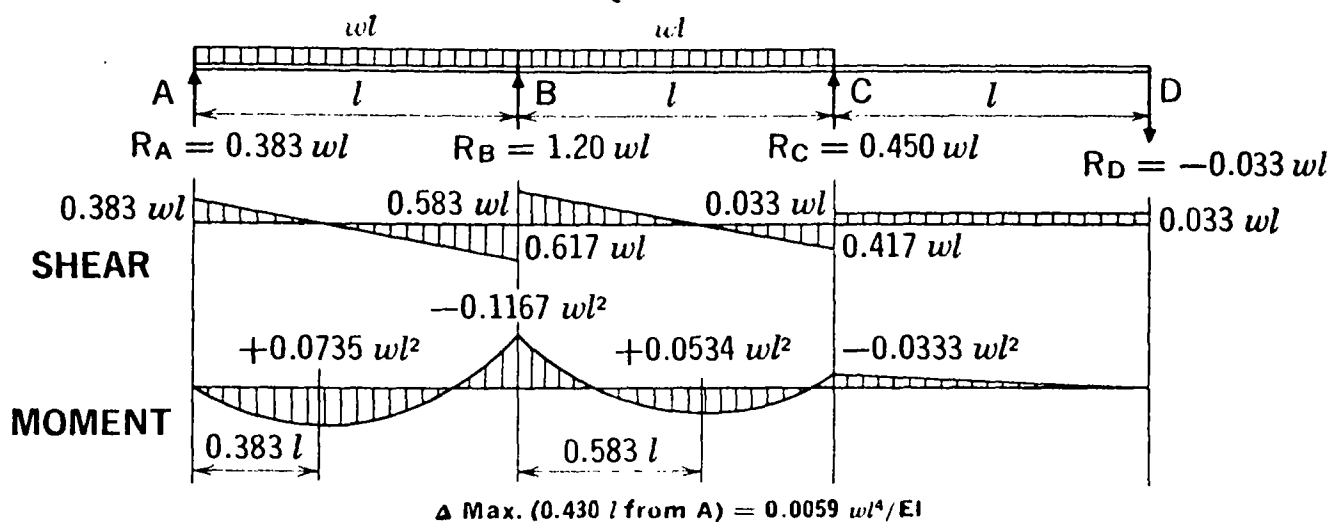
$$\Delta_a \text{ (at point of load)} = \frac{Pb^2}{3EI}$$

$$\Delta_x \text{ (when } x < a) = \frac{Pb^2}{6EI} (3l - 3x - b)$$

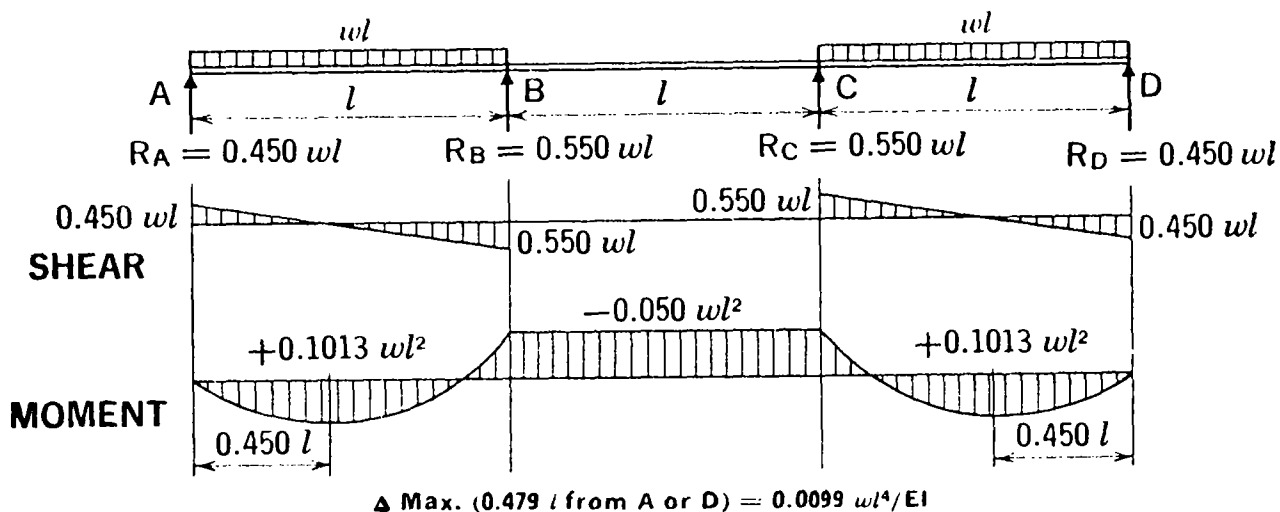
$$\Delta_x \text{ (when } x > a) = \frac{P(l-x)^2}{6EI} (3b - l - x)$$

Figure 14-5—Continued.

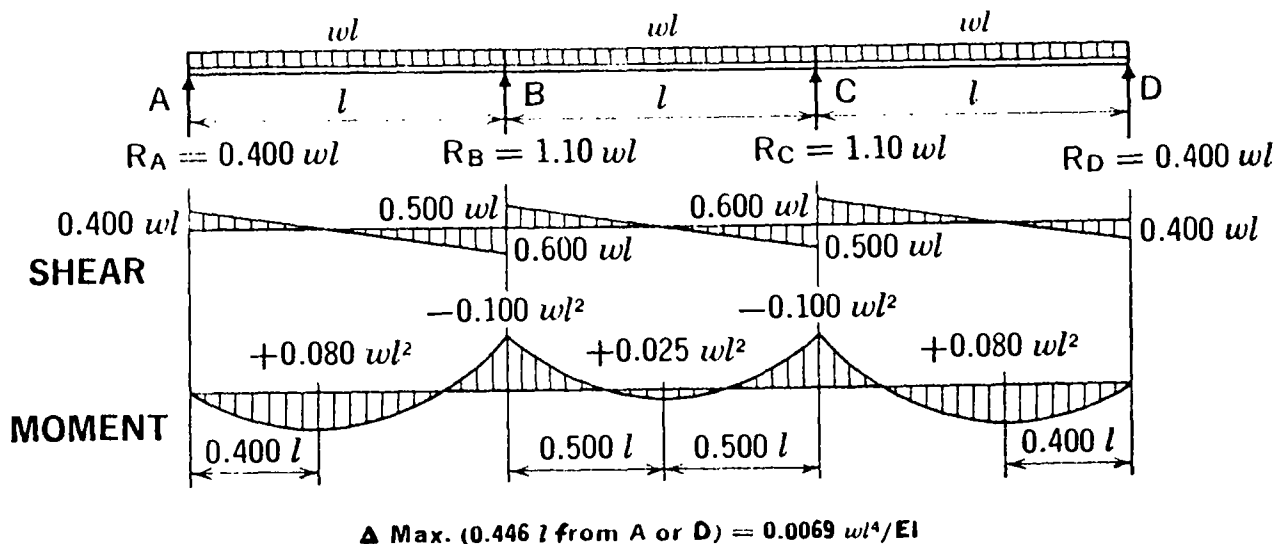
CONTINUOUS BEAM—THREE EQUAL SPANS—ONE END SPAN UNLOADED



CONTINUOUS BEAM—THREE EQUAL SPANS—END SPANS LOADED



CONTINUOUS BEAM—THREE EQUAL SPANS—ALL SPANS LOADED



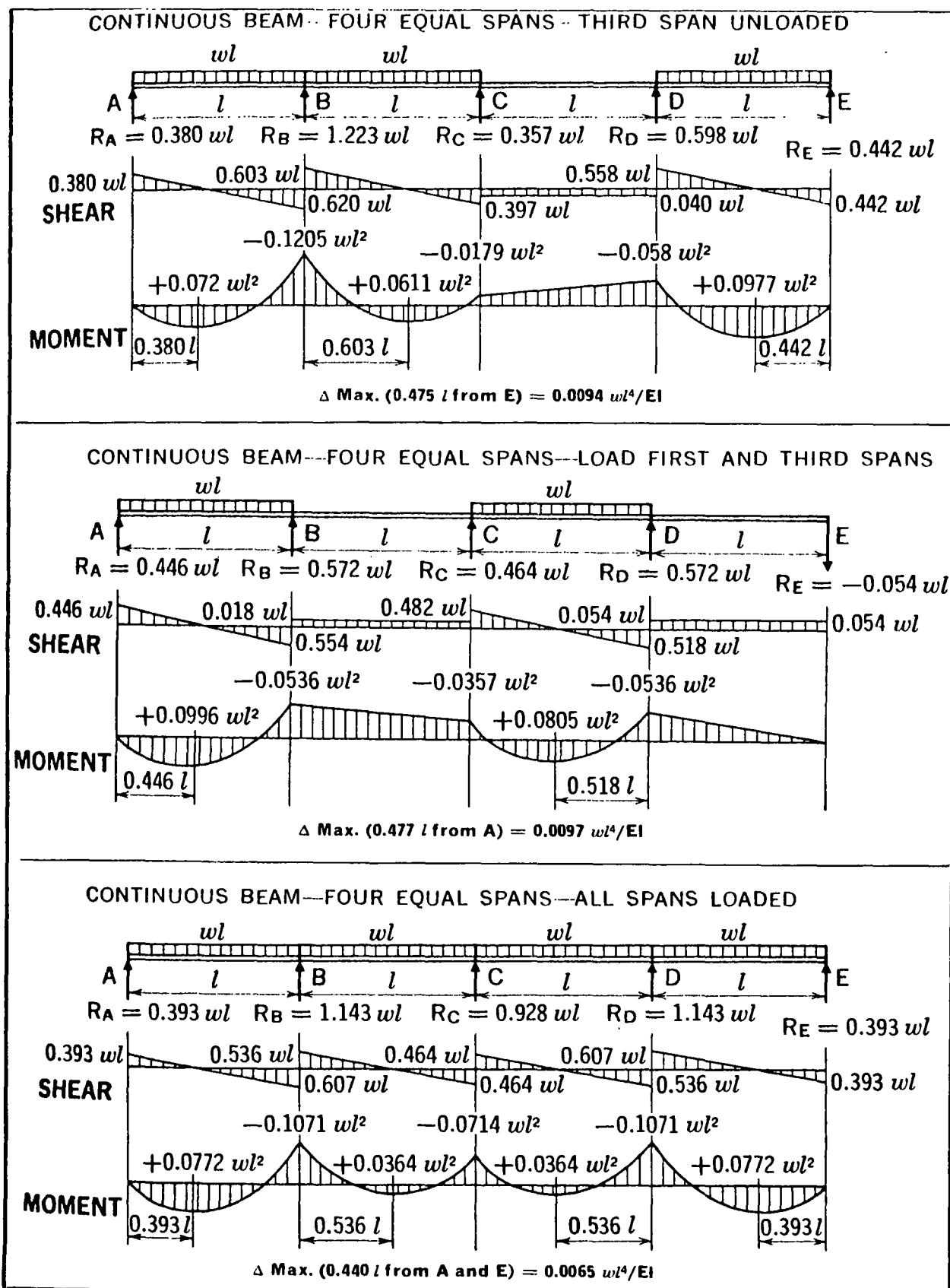
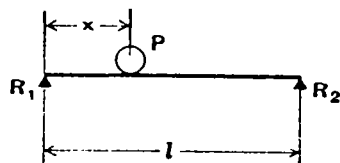


Figure 14-6—Continued.

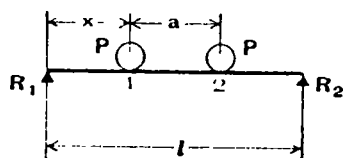
SIMPLE BEAM—ONE CONCENTRATED MOVING LOAD



$$R_1 \text{ max.} = V_1 \text{ max. (at } x = 0) \quad \dots \quad = P$$

$$M \text{ max. (at point of load, when } x = \frac{l}{2}) \quad \dots \quad = \frac{Pl}{4}$$

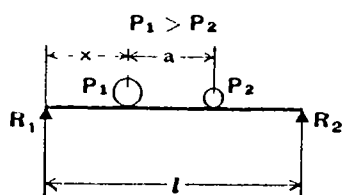
SIMPLE BEAM—TWO EQUAL CONCENTRATED MOVING LOADS



$$R_1 \text{ max.} = V_1 \text{ max. (at } x = 0) \quad \dots \quad = P \left(2 - \frac{a}{l}\right)$$

$$M \text{ max.} \begin{cases} \left[\begin{array}{l} \text{when } a < (2 - \sqrt{2}) l = .586 l \\ \text{under load 1 at } x = \frac{1}{2} \left(l - \frac{a}{2} \right) \end{array} \right] & = \frac{P}{2l} \left(l - \frac{a}{2} \right)^2 \\ \left[\begin{array}{l} \text{when } a > (2 - \sqrt{2}) l = .586 l \\ \text{with one load at center of span} \\ \text{(case 40)} \end{array} \right] & = \frac{Pl}{4} \end{cases}$$

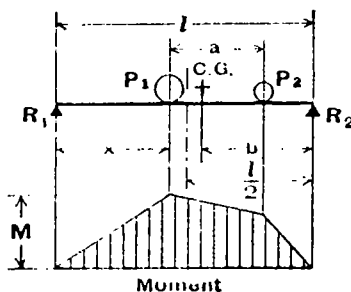
SIMPLE BEAM—TWO UNEQUAL CONCENTRATED MOVING LOADS



$$R_1 \text{ max.} = V_1 \text{ max. (at } x = 0) \quad \dots \quad = P_1 + P_2 \frac{l-a}{l}$$

$$M \text{ max.} \begin{cases} \left[\text{under } P_1, \text{ at } x = \frac{1}{2} \left(l - \frac{P_2 a}{P_1 + P_2} \right) \right] = (P_1 + P_2) \frac{x^2}{l} \\ \left[\begin{array}{l} M \text{ max. may occur with larger} \\ \text{load at center of span and other} \\ \text{load off span (case 40)} \end{array} \right] & = \frac{P_1 l}{4} \end{cases}$$

GENERAL RULES FOR SIMPLE BEAMS CARRYING MOVING CONCENTRATED LOADS



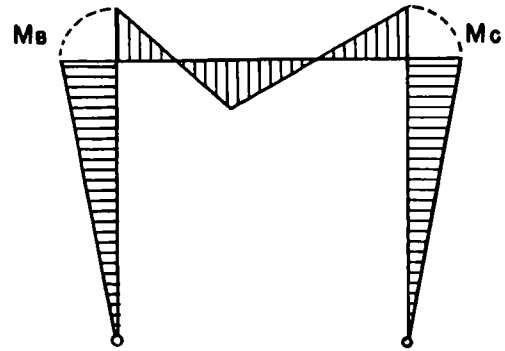
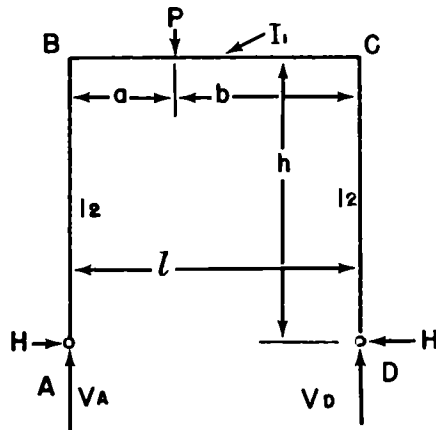
The maximum shear due to moving concentrated loads occurs at one support when one of the loads is at that support. With several moving loads, the location that will produce maximum shear must be determined by trial.

The maximum bending moment produced by moving concentrated loads occurs under one of the loads when that load is as far from one support as the center of gravity of all the moving loads on the beam is from the other support.

In the accompanying diagram, the maximum bending moment occurs under load P_1 when $x = b$. It should also be noted that this condition occurs when the center line of the span is midway between the center of gravity of loads and the nearest concentrated load.

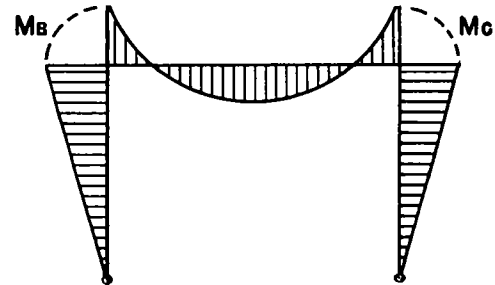
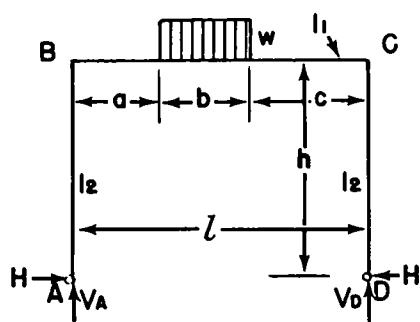
Figure 14-7. Diagrams and formulas for moving loads.

Concentrated vertical load.



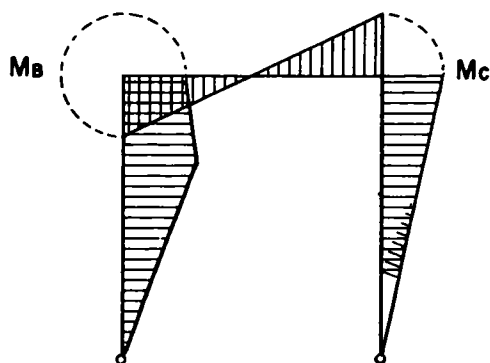
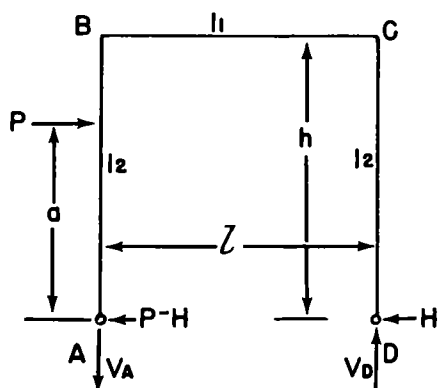
General Case	Load in Center $a = b$
$H = \frac{3Pab}{2h(2k + 3)} ; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$	$H = \frac{3Pl}{8h(2k + 3)} ; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$
$V_A = \frac{Pb}{l} \quad V_D = \frac{Pa}{l}$	$V_A = \frac{P}{2} \quad V_D = \frac{P}{2}$
$M_B = M_C = -Hh$	$M_B = M_C = -Hh$

Uniformly distributed vertical load.

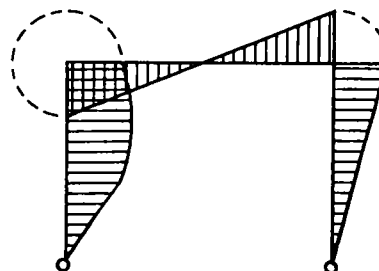
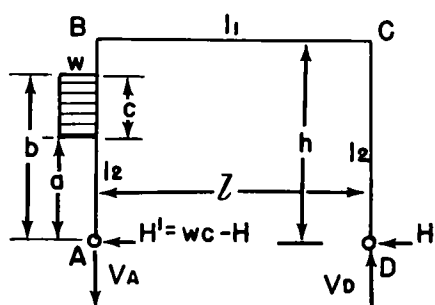


General Case	Top Fully Loaded $b = l$
$H = \frac{wb}{4} \cdot \frac{6ac + b(3l + 2b)}{h(2k + 3)} ; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$	$H = \frac{wl}{4h(2k + 3)} ; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$
$V_A = \frac{wb}{2l} (2c + b) ; V_D = \frac{wb}{2l} (2a + b)$	$V_A = V_D = \frac{wl}{2}$
$M_B = M_C = -Hh$	$M_B = M_C = -Hh$

Figure 14-8. Stresses in rigid frames.

Concentrated horizontal load.

General Case	Load at B $a = h$
$H = \frac{Pa}{2} \cdot \frac{3h^2 + k(3h^2 - a^2)}{h^3(2k + 3)}; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$	$H = \frac{P}{2}$
$V_A = V_D = \frac{Pa}{l}$	$V_A = V_D = \frac{Ph}{l}$
$M_B = Pa - Hh; M_C = -Hh$	$M_B = +\frac{1}{2}Ph; M_C = -\frac{1}{2}Ph$

Uniformly distributed horizontal load.

General Case	Side Fully Loaded; $c = h$
$H = \frac{w [6h^2(l+k)(b^2-a^2) - k(b^4-a^4)]}{8h^3(2k+3)}$	$H = \frac{wh}{8} \cdot \frac{6 + 5h}{2k + 3}$
$V_A = V_D = \frac{w(b^2 - a^2)}{2l}; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$	$V_A = V_D = \frac{wh^2}{2l}; k = \frac{l_1}{l_2} \cdot \frac{h}{l}$
$M_B = V_D l - Hh; M_C = -Hh$	$M_B = V_D l - Hh; M_C = -Hh$

Figure 14-8—Continued.

e. Rigid Frame.

(1) Stresses in rigid frames, for various conditions of static loading, are given in figure 14-8.

(2) Approximate analysis of indeterminate structures can be made on simple rigid structures by making reasonable assumptions. The number

of assumptions made must equal the degree to which the structure is indeterminate.

(a) Stresses in building frames due to vertical loads. The following assumptions can be made for each girder in analyzing a building frame acted upon by vertical loads. See figure 14-9.

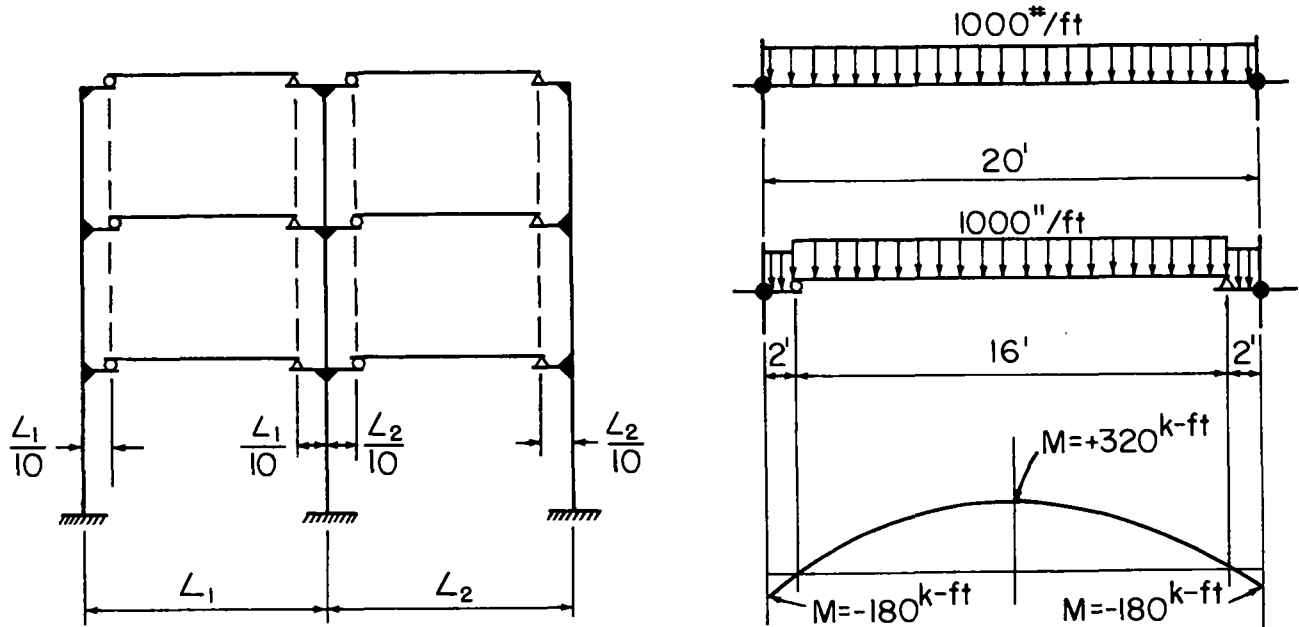


Figure 14-9. Illustration of possible assumptions in building girder analysis.

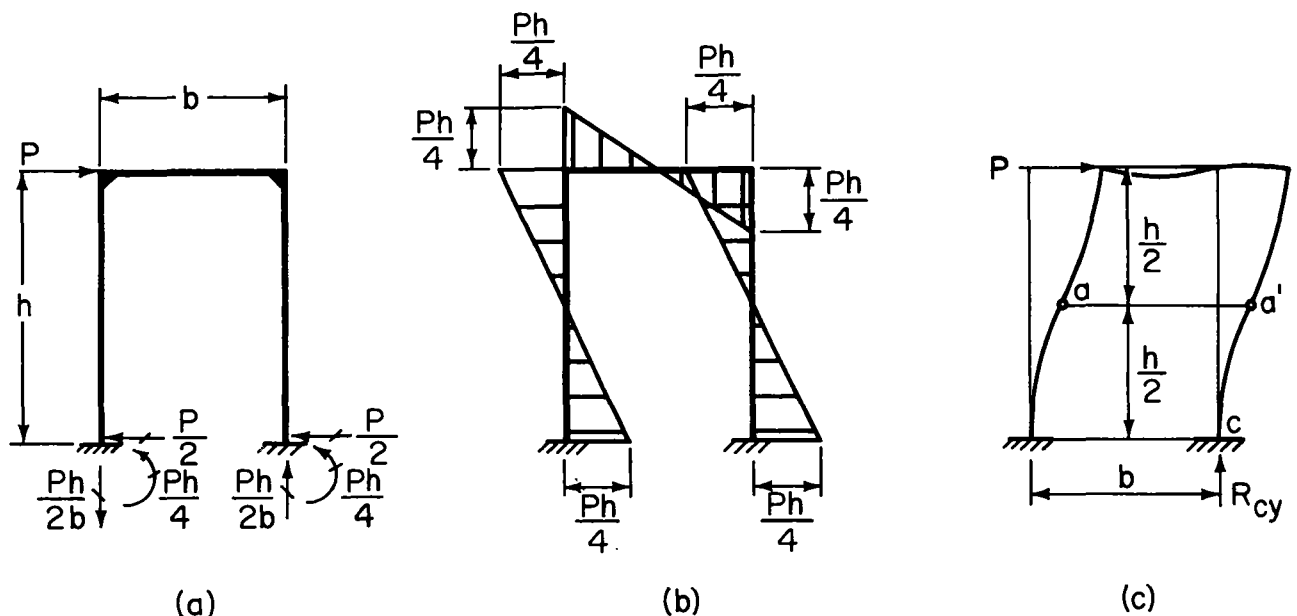


Figure 14-10. Illustration of possible assumptions in building frame analysis.

1. The axial force in the girder is zero.
2. A point of inflection occurs at the one-tenth point measured along the span from the left support.
3. A point of inflection occurs at the one-tenth point measured along the span from the right support.

(b) Stresses in building frames due to lateral loads. The following assumptions can be made in the portal method. See figure 14-10.

1. There is a point of inflection at the center of each girder.
2. There is a point of inflection at the center of each column.
3. The total horizontal shear on each story is divided between the columns of that story in a manner such that each interior column carries twice as much shear as each exterior column.

(c) In the cantilever method the third assumption of the portal method is replaced by the following assumption (fig 14-11).

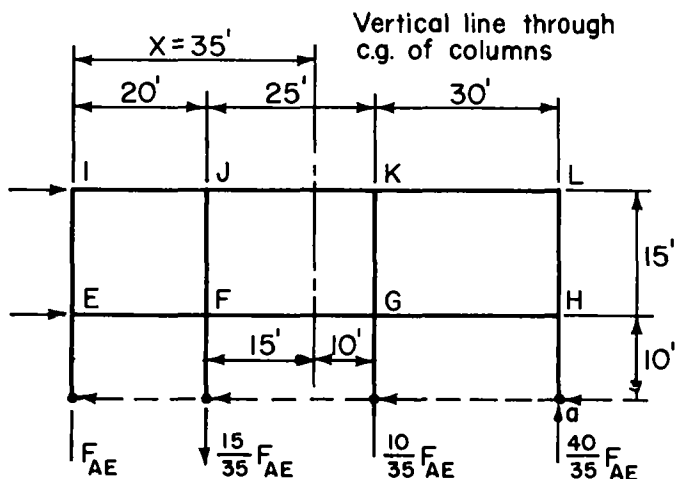


Figure 14-11. Illustration of assumption for building analysis by cantilever method.

1. There is a point of inflection at the center of each girder.
2. There is a point of inflection at the center of each column.
3. The intensity of axial stress in each column of a story is proportional to the horizontal distance of that column from the center of gravity of all the columns of the story under consideration.

f. Trusses. For common types of trusses, stress factors based on symmetrical vertical loads only,

and on equal panel lengths and panel loads, are given in figure 14-12. In the truss diagrams shown, compression members are indicated by heavy lines, tension members by light lines.

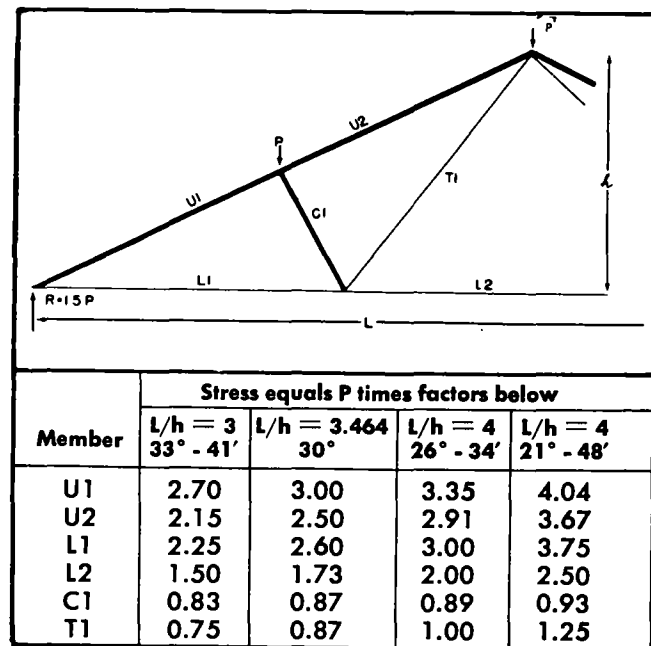


Figure 14-12. Stresses in truss members.

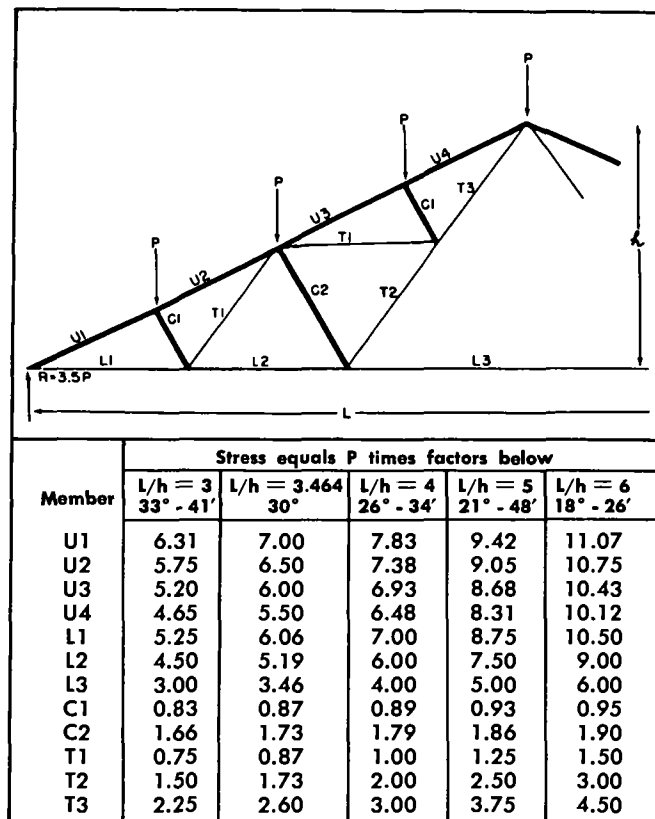


Figure 14-12—Continued.

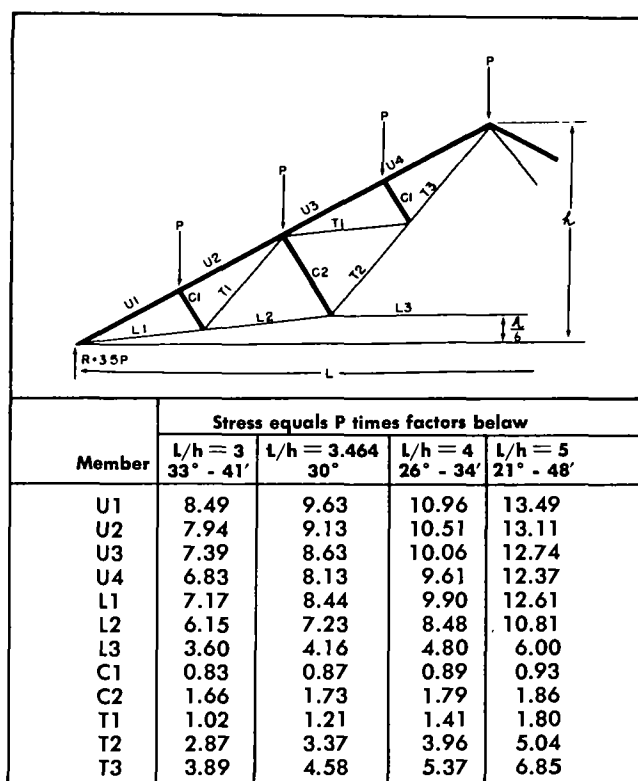
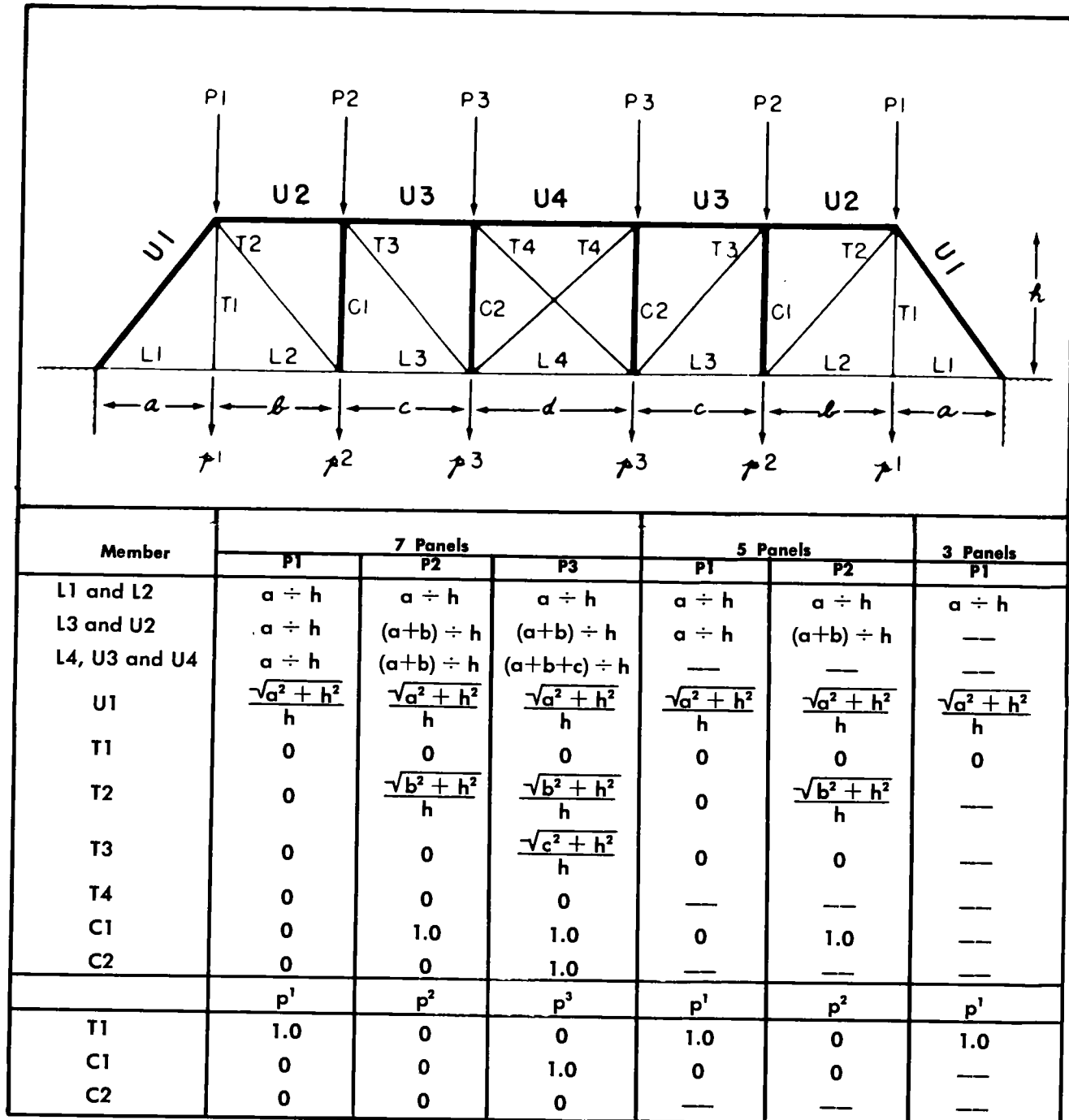


Figure 14-12—Continued.



NOTES: For loads p_1 , p_2 , etc., the coefficients for the chords and diagonals are the same as given for the loads P_1 , P_2 , etc. The coefficients for the verticals for loads p_1 , p_2 , etc., are given in the supplementary table below the general table.

Figure 14-12—Continued.

Section III. STRUCTURAL STEEL

14-13. General

For permanent construction, the allowable unit stresses are given in the Manual of Steel Construction (Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings) of the American Institute of Steel Construction. For military construction in a theater of operations, the allowable unit stresses in structural steel, rivets, bolts, and welds are based on ASTM A36 structural steel with minimum yield strength of 36 ksi. Allowable stresses for military construction in the theater of operations are greater than those specified in the Manual of Steel Construction, these are also listed in the event that the specifications can be met in the theater of operations.

14-14. Allowable Stresses

a. Tension.

- (1) Structural steel, net section - 29,000 psi
Bolts at root of thread - 22,000
Butt welds, section through throat - 22,000
- (2) AISC Specifications:
On the net section, except at pin holes - $F_t = 0.60 F_y$
On the net section at pin holes - $F_t = 0.45 F_y$

b. Compression.

- (1) Plate girder stiffeners,
gross section - 29,000 psi
Columns axial compression, gross section, for values of l/r not over 120 - $18,000 - 0.6(l/r)^2$
Butt welds, section through throat (crushing) - 26,400

(2) AISC Specifications:

(a) On the gross section of axially loaded compression members when Kl/r , the largest effective slenderness ratio of any unbraced segment as defined in paragraph 14-16, is less than C_c .

$$F_a = \frac{\left[1 - \frac{(Kl/r)^2}{2C_c^2}\right] F_y}{F.S.}$$

Where:

$$F.S. = \text{factor of safety} = \frac{5}{3} + \frac{3(Kl/r)}{8C_c} - \frac{(Kl/r)^3}{8C_c^3}$$

$$C_c = \text{column slenderness ratio} = \sqrt{\frac{2\pi^2 E}{F_y}}$$

and

F_a = axial stress permitted in the absence of bending moment.

($C_c = 126.1$ for A36 Structural Steel)

(b) On the gross section of axially loaded columns when Kl/r exceeds C_c .

$$F_a = \frac{149 \times 10^6}{(Kl/r)^2}$$

(c) On the gross section of axially loaded bracing and secondary members, when l/r exceeds 120

$$F_{as} = \frac{F_a \text{ (of either (1) or (2) above)}}{1.6 - \frac{1}{200r}}$$

Where F_{as} = axial compressive stress permitted in the absence of bending moment for bracing and other secondary members.

(d) On the gross area of plate girder stiffeners $F_a = 0.60 F_y$.

c. Bending.

(1) Extreme fibers of rolled sections, plate girders and built-up members:

Tension	29,000 psi
Compression	$29,000 - 0.679(l/r)^2$
Butt welds	Same as above for tension and compression.

(2) AISC Specifications:

(a) Tension and compression on extreme fibers of laterally supported compact rolled shapes and compact built-up members having an axis of symmetry in the plane of loading. $F_b = 0.66 F_y$

(b) Tension and compression on extreme fibers of unsymmetrical members, except channels, supported in the region of compression stress - $F_b = 0.60 F_y$

(c) Tension on extreme fibers of other rolled shapes, built-up members, and plate girders - $F_b = 0.60 F_y$

(d) Tension and compression on extreme fibers of rectangular bearing plates. $F_b = 0.75 F_y$

d. Shear.

(1) Rivets and pins	22,000 psi
Girder web, gross section	18,400
Weld metal, on section through throat of fillet weld or on faying (contact) surface area at plug or slot weld	14,500 psi

(2) AISC Specifications:

On the gross section ---- $F_v = 0.40 F_y$

e. *Bearing.*

Rivets and bolts (ASTM A325

Steel) ----- 48,500

Pins ----- 33,000

Contact area:

Milled stiffeners and other

milled surfaces ----- 33,000

Fitted stiffeners ----- 29,000

Expansion rollers or rockers

(d = diameter of roller or

rocker) ----- 760 d

f. *Masonry Bearing.*

Granite ----- 800 psi

Sandstone and limestone ---- 400

Brick in cement mortar ---- 250

Portland cement concrete --- 600

g. Wind and Seismic Stresses. Allowable stresses may be increased by one-third above the values provided in *a* through *f* above, when produced by wind or seismic in combination with the dead load and live load.

14-15. Beams

A beam is subject principally to vertical loads, which cause shear and bending moment in the member. Flexural and shear stresses on a beam can be obtained by the use of formulas listed in the previous paragraph.

a. Design Procedures. If a beam is to be tension member, the following design procedures apply:

(1) Using the equation $F_b = P/A$, determine the net area *A* required.

(2) Estimate the number of rows of rivet holes that will occur at the critical net section.

(3) Estimate the thickness of the membrane and the amount of cross-sectional area removed by these holes.

(4) Add the required net area to the estimated area removed by the holes to obtain the approximate total cross-sectional area.

(5) Select a section having this value of gross area.

(6) For the section selected, compute the net area.

(7) If the net area is insufficient, repeat the process with another section.

(8) Check the slenderness ratio of the member.

b. *Web Crippling.*

(1) To avoid web crippling, beams are designed so the compression stress in the web at the toe of the fillet, resulting from reactions or concentrated loads, shall not exceed 0.75 F_y pounds per square inch. The governing formulas are—

for interior loads

$$\frac{R}{t(N + 2K)} < 0.75 F_y$$

and for end reactions

$$\frac{R}{t(N + K)} < 0.75 F_y$$

Where:

R = concentrated load or reaction, in pounds

t = thickness of web, in inches

N = length of bearing, in inches

K = distance from outer face of flange to web toe of fillet, in inches.

(2) Webs of plate girders must also be stiffened so that the sum of compression stresses resulting from concentrated or distributed loads, bearing directly on or through a flange plate, upon the compression edge of the web plate, and not supported by bearing stiffeners, is—

$$F_c < \left[5.5 + \frac{4}{(a/h)^2} \right] \frac{10 \times 10^6}{(h/t)^2} \frac{1b}{in^2} \text{ when the flange is restrained against rotation and}$$

$$F_c < \left[2 + \frac{4}{(a/h)^2} \right] \frac{10 \times 10^6}{(h/t)^2} \frac{1b}{in^2} \text{ when the flange is not so restrained.}$$

a = clear distance between transverse stiffeners

h = clear distance between flanges

t = web thickness

c. *Deflection.*

(1) The maximum deflection for a simple symmetrical simply supported beam or girder uniformly loaded is

$$\Delta = \frac{5 W l^3}{384 EI}$$

Where:

Δ = deflection in inches

W = total uniform load plus weight of beam

l = span in inches.

(2) Beams and girders supporting plastered ceilings shall be so proportioned that the maximum live load deflection will not exceed 1/360 of the span.

d. Lateral Support of Beams. Lateral buckling occurs in the compression flange when the ultimate load is applied. The factors which affect the critical compressive stress include the type of loading, conditions of end restraint of the compression flange, position and type of intermediate supports, the support which the web offers against lateral buckling, the properties of flange itself, and the modulus of elasticity of the material. In general, L_u , the maximum unbraced length of compression flange for A-36 steel is

$$L_u = \frac{545}{12 (d/A_f)}$$

Where:

d = depth of beam in inches

A_f = area of flange (sq in)

L_u = maximum unbraced length

14-16. Columns

a. Design Procedures. Since the allowable stress, F_a , for a column is not known until a section has been chosen and its slenderness ratio L/r computed, the selection of a column section is by successive approximation.

(1) Assume a logical value of F_a and compute the approximate area required.

(2) Select a trial section and compute the maximum slenderness ratio for that section.

(3) Determine the allowable average stress and compare it with the actual average stress, F_a , for the trial section. If the actual does not exceed the allowable, the section is satisfactory.

(4) If the section is satisfactory, examine the list of available sections to determine if a more economical section can be found. If the section is unsatisfactory, repeat the procedure with another section.

b. Slenderness Ratio.

(1) Most steel structure specifications require that the slenderness ratio L/r of tension or compression members be limited to not more than a stated maximum allowable value. The purpose of an upper limit of slenderness ratio is to insure reasonable stiffness of the structure and to reduce undesirable deflection and excessive vibration under mooring loads. The maximum allowable ratios are as follows:

Compression members shall not exceed	120
Tension members, other than rods,	
should not exceed:	
for main members	240
for bracing and other	
secondary members	300

(2) The stiffness of columns also depend on the conditions of end support. There each column length is adjusted by K , the effective length factor, and the slenderness ratio is taken to be KL/r . The recommended values of K are found in figure 14-13.

14-17. Connections

a. Bolts.

(1) Effective bearing area of bolts is equal to the diameter multiplied by the length in bearing.

(2) The minimum distance between centers of bolt holes shall be not less than $2\frac{2}{3}$ times the nominal diameter of the bolt but preferably not less than 3 diameters.

(3) The minimum distance from the center of a bolt hole to any edge shall be that given in table 14-10.

Table 14-10. Minimum Distance From Center of Hole to Edge of Steel

Bolt diameter (inches)	Minimum edge distance for punched, reamed, or drilled holes (inches)	
	At sheared edges	At rolled edges of plates, shapes or bars or gas cut edges**
$\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{4}$
$\frac{5}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$
$\frac{3}{4}$	$1\frac{1}{4}$	1
$\frac{7}{8}$	$1\frac{1}{2}$ *	$1\frac{1}{8}$
1	$1\frac{3}{4}$ *	$1\frac{1}{4}$
$1\frac{1}{8}$	2	$1\frac{1}{2}$
$1\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{5}{8}$
Over $1\frac{1}{4}$	$1\frac{3}{4}$ x diameter	$1\frac{1}{4}$ x diameter

*These may be $1\frac{1}{4}$ in. at the ends of beam connection angles.

**All edge distances in this column may be reduced $\frac{1}{8}$ in. when the hole is at a point where stress does not exceed 25% of the maximum allowed stress in the element.

(4) The maximum distance from the center of any bolt to the nearest edge of parts in contact with one another shall be 12 times the thickness of the plate, but not to exceed 6 inches.

b. Welds.

(1) *Action.* A butt weld acts only in direct tension or compression. A fillet weld, being placed on the side or edge of the base metal, is undergoing shear as well as tension or compression and usually also flexure.

(2) *Stresses.* Working stresses specified by the American Welding Society and AISC are as follows:

F_v = 14,000 psi on throat of butt weld	} or same as base steel
F_v = 14,500 psi on throat of fillet weld	
F_t = 22,000 psi	
F_c = 26,400 psi	

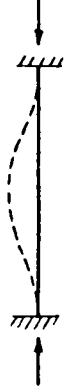
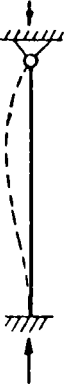
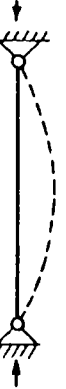
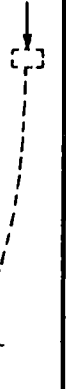
Buckled shape of column is shown by dashed line	(a) 	(b) 	(c) 	(d) 	(e) 	(f) 
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.10	2.0
End condition code		Rotation fixed and translation fixed Rotation free and translation fixed Rotation fixed and translation free Rotation free and translation free				

Figure 14-13. K factors for column design.(3) *Effective areas of weld.*

(a) The effective area of butt and fillet welds shall be the effective length of weld times the effective throat thickness.

(b) The effective throat thickness of a fillet weld shall be the shortest distance from the root to the face of the diagrammatic weld. See figure 14-14. The effective throat thickness of an equal leg 45° fillet weld is 0.707 times the nominal size of the weld. See table 14-11.

(4) *Minimum size of fillet welds.* Weld size is determined by the thicker of the two parts

joined, except that the weld size need not exceed the thickness of the thinner part unless a larger size is required by calculated stress.

(5) *Length of fillet welds.* The minimum effective length of a strength fillet weld shall not be less than 4 times the nominal size, or else the size of the weld shall be considered not to exceed one-fourth of its effective length.

14-18. Dimensions and Properties

Tables 14-12 through 14-17 give dimensions and properties of common steel members.

Table 14-11. *Effective Weld Areas*

Type of weld	Effective length	Effective throat thickness
Butt welds, complete penetration. Butt welds, incomplete penetration.	Width of part joined.	Thickness of thinner part joined. 75% of thickness of thinner part joined.
Fillet welds	Overall length of full size fillet, including returns.	Shortest distance from root to face (0.707 times nominal size for an equal-leg 45° weld).
Plug and slot welds	Shearing area is nominal area of hole or slot in plane of faying (contact) surface.	
Fillet welds in holes or slots.	Shearing area is effective area of fillet, but not to exceed nominal area of hole or slot.	

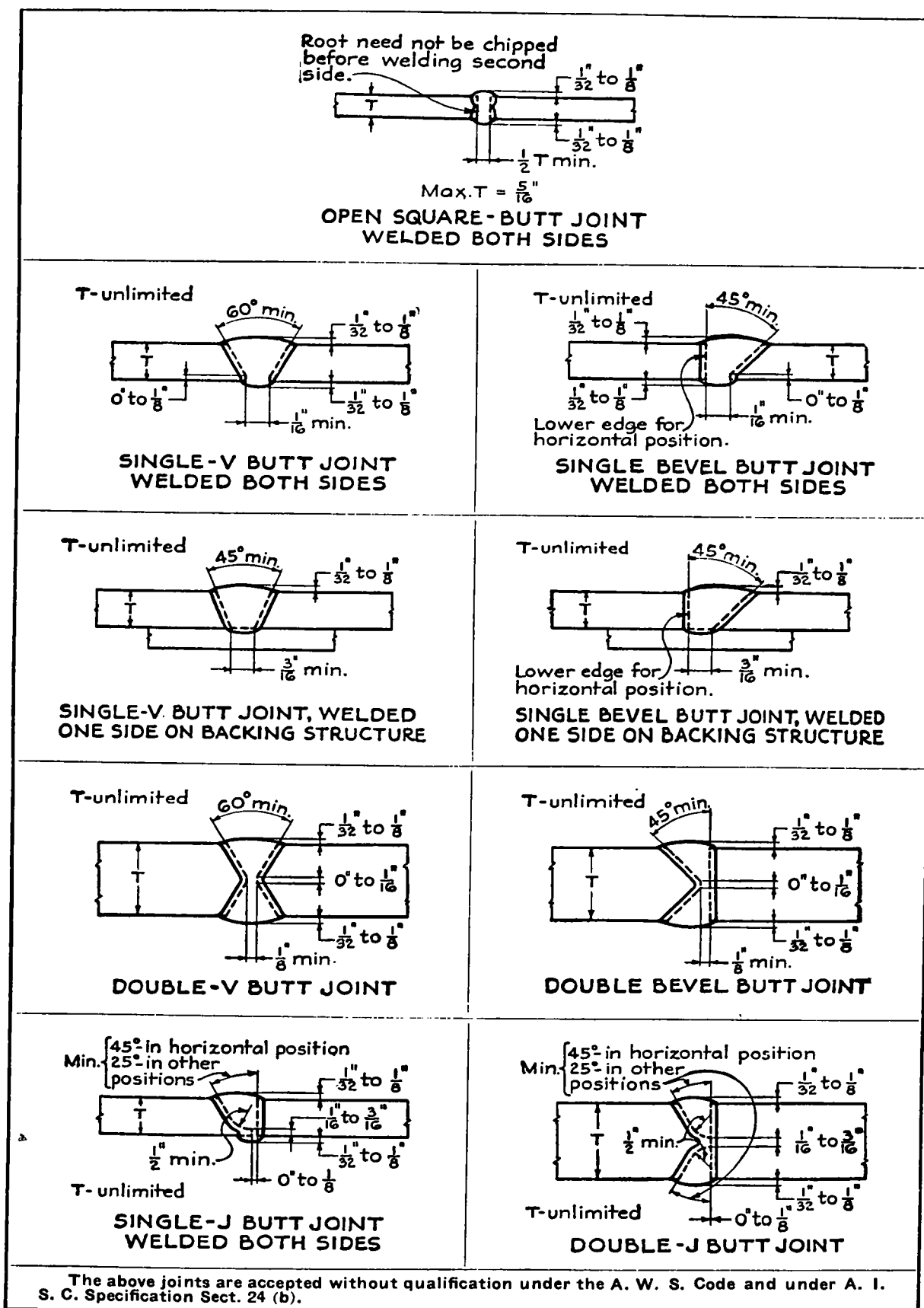


Figure 14-14. Details of joint welds.

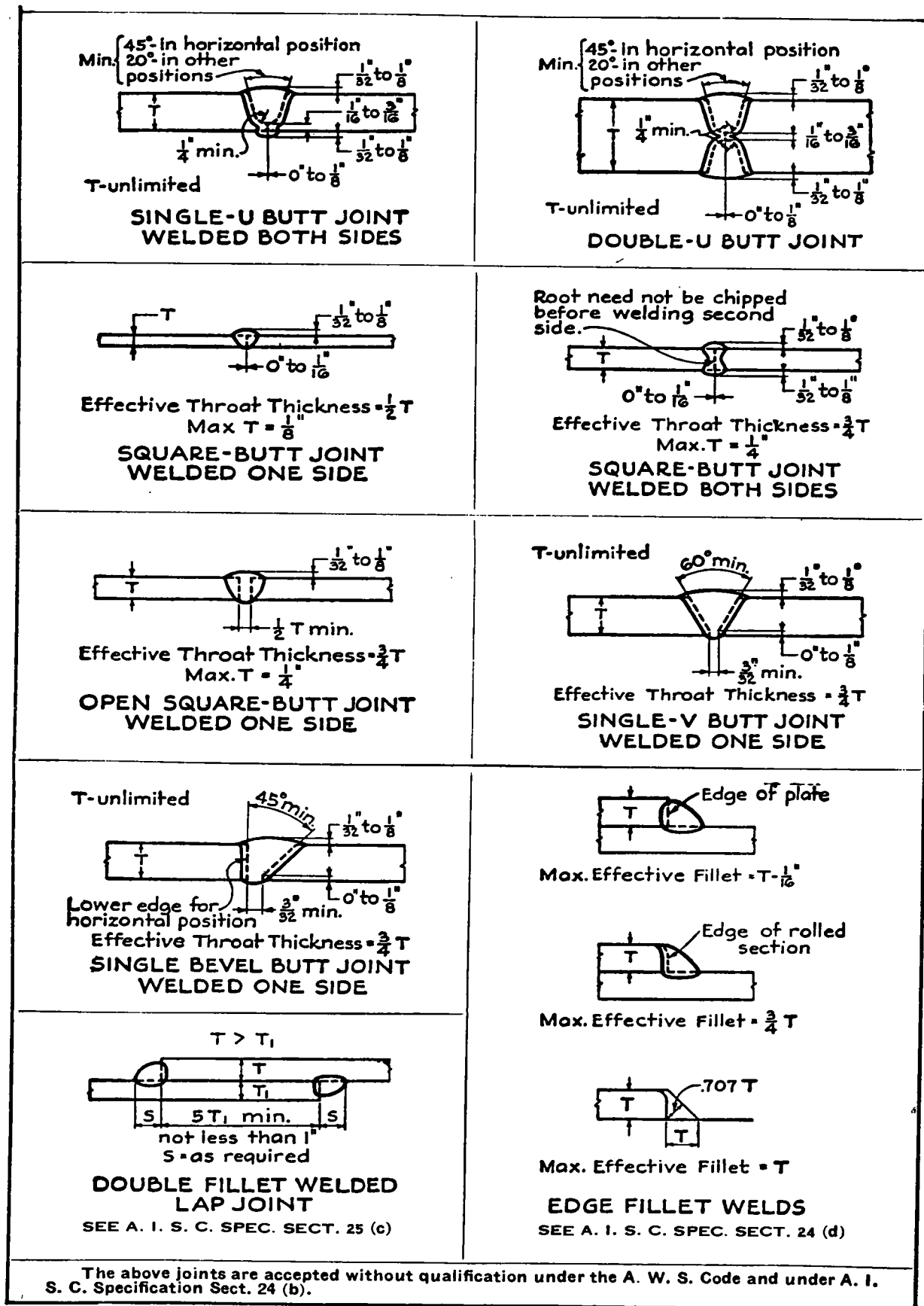


Figure 14-14. Details of joint welds—Continued.

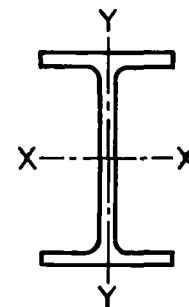


Table 14-12. WF Shapes

Nominal size	Weight per foot	Area	Depth	Flange		Web thickness	Axis X-X			Axis Y-Y			Gage
				Width	Thickness		I	S	r	I	S	r	
In.	Lb.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
36 x 16½	230	67.73	35.88	16.475	1.260	.765	14988.4	835.5	14.88	870.9	105.7	3.59	5½
36 x 12	150	44.16	35.84	11.972	.940	.625	9012.1	502.9	14.29	250.4	41.8	2.38	5½
33 x 11½	130	38.26	33.10	11.510	.855	.580	6699.0	404.8	13.23	201.4	35.0	2.29	5½
30 x 15	172	50.65	29.88	14.985	1.065	.655	7891.5	528.2	12.48	550.1	73.4	3.30	5½
30 x 10½	108	31.77	29.82	10.484	.760	.548	4461.0	299.2	11.85	135.1	25.8	2.06	5½
27 x 10	94	27.65	26.91	9.990	.747	.490	3266.7	242.8	10.87	115.1	23.0	2.04	5½
24 x 12	100	29.43	24.00	12.000	.775	.468	2987.3	248.9	10.08	203.5	33.9	2.63	5½
24 x 9	76	22.37	23.91	8.985	.682	.440	2096.4	175.4	9.68	76.5	17.0	1.85	5½
21 x 8¾	62	18.23	20.99	8.240	.615	.400	1326.8	126.4	8.53	53.1	12.9	1.71	5½
18 x 7½	50	14.71	18.00	7.500	.570	.358	800.6	89.0	7.38	37.2	9.9	1.59	3½
16 x 7	36	10.59	15.85	6.992	.428	.299	446.3	56.3	6.49	22.1	6.3	1.45	3½
14 x 6¾	30	8.81	13.86	6.733	.383	.270	289.6	41.8	5.73	17.5	5.2	1.41	3½
12 x 12	65	19.11	12.12	12.000	.606	.390	533.4	88.0	5.28	174.6	29.1	3.02	5½
12 x 6½	27	7.97	11.95	6.500	.400	.240	204.1	34.1	5.06	16.6	5.1	1.44	3½
10 x 10	49	14.40	10.00	10.000	.558	.340	272.9	54.6	4.35	93.0	18.6	2.54	5½
10 x 5¾	21	6.19	9.90	5.750	.340	.240	106.3	21.5	4.14	9.7	3.4	1.25	2¾
8 x 8	31	9.12	8.00	8.000	.433	.288	109.7	27.4	3.47	37.0	9.2	2.01	5½
8 x 6½	24	7.06	7.93	6.500	.398	.245	82.5	20.8	3.42	18.2	5.6	1.61	3½
8 x 5½	17	5.00	8.00	5.250	.308	.230	56.4	14.1	3.36	6.7	2.6	1.16	2¾
6 x 6	25	7.37	63.7	8.080	.456	.320	53.5	16.8	2.69	17.1	5.6	1.52	3½
4 x 4	13	3.82	4.16	4.060	.345	.280	11.3	5.45	1.72	3.76	1.85	.99	2¾

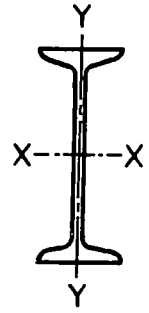


Table 14-13. American Standard Beams

Nominal size	Weight per foot	Area	Depth	Flange		Web thickness	Axis X-X			Axis Y-Y		
				Width	Thickness		I	S	r	I	S	r
In.	Lb.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
24 x 7 $\frac{7}{8}$ -----	120.0	35.13	24.00	8.048	1.102	0.798	3010.8	250.9	9.26	84.9	21.1	1.56
	105.9	30.98	24.00	7.875	1.102	.625	2811.5	234.3	9.53	78.9	20.1	1.60
24 x 7 -----	100.0	29.25	24.00	7.247	.871	.747	2371.8	197.6	9.05	48.4	13.4	1.29
	90.0	26.30	24.00	7.124	.871	.624	2230.1	185.8	9.21	45.5	12.8	1.32
	79.9	23.33	24.00	7.000	.871	.500	2087.2	173.9	9.46	42.9	12.2	1.36
20 x 7 -----	95.0	27.74	20.00	7.200	.916	.800	1599.7	160.0	7.59	50.5	14.0	1.35
	85.0	24.80	20.00	7.053	.916	.653	1501.7	150.2	7.78	47.0	13.3	1.38
20 x 6 $\frac{1}{4}$ -----	75.0	21.90	20.00	6.391	.789	.641	1263.5	126.3	7.60	30.1	9.4	1.17
	65.4	19.08	20.00	6.250	.789	.500	1169.5	116.9	7.83	27.9	8.9	1.21
18 x 6 -----	70.0	20.46	18.00	6.251	.691	.711	917.5	101.9	6.70	24.5	7.8	1.09
	54.7	15.94	18.00	6.000	.691	.460	795.5	88.4	7.07	21.2	7.1	1.15
15 x 5 $\frac{1}{2}$ -----	50.0	14.59	15.00	5.640	.622	.550	481.1	64.2	5.74	16.0	5.7	1.05
	42.9	12.49	15.00	5.500	.622	.410	441.8	58.9	5.95	14.6	5.3	1.08
12 x 5 $\frac{1}{4}$ -----	50.0	14.57	12.00	5.477	.659	.687	301.6	50.3	4.55	16.0	5.8	1.05
	40.8	11.84	12.00	5.250	.659	.460	268.9	44.8	4.77	13.8	5.3	1.08
12 x 5 -----	35.0	10.20	12.00	5.078	.544	.428	227.0	37.8	4.72	10.0	3.9	.99
	31.8	9.26	12.00	5.000	.544	.350	215.8	36.0	4.83	9.5	3.8	1.01
10 x 4 $\frac{5}{8}$ -----	35.0	10.22	10.00	4.944	.491	.594	145.8	29.2	3.78	8.5	3.4	.91
	25.4	7.38	10.00	4.660	.491	.310	122.1	24.4	4.07	6.9	3.0	.97
8 x 4 -----	23.0	6.71	8.00	4.171	.425	.441	64.2	16.0	3.09	4.4	2.1	.81
	18.4	5.34	8.00	4.000	.425	.270	56.9	14.2	3.26	3.8	1.9	.84
7 x 3 $\frac{5}{8}$ -----	20.0	5.83	7.00	3.860	.392	.450	41.9	12.0	2.68	3.1	1.6	.74
	15.3	4.43	7.00	3.660	.392	.250	36.2	10.4	2.86	2.7	1.5	.78
6 x 3 $\frac{5}{8}$ -----	17.25	5.02	6.00	3.565	.359	.465	26.0	8.7	2.28	2.3	1.3	.68
	12.5	3.61	6.00	3.330	.359	.230	21.8	7.3	2.46	1.8	1.1	.72
5 x 3 -----	14.75	4.29	5.00	3.284	.326	.494	15.0	6.0	1.87	1.7	1.0	.63
	10.0	2.87	5.00	3.000	.326	.210	12.1	4.8	2.05	1.2	.82	.65
4 x 2 $\frac{5}{8}$ -----	9.5	2.76	4.00	2.796	.293	.326	6.7	3.3	1.56	.91	.65	.58
	7.7	2.21	4.00	2.660	.293	.190	6.0	3.0	1.64	.77	.58	.59
3 x 2 $\frac{5}{8}$ -----	7.5	2.17	3.00	2.509	.260	.349	2.9	1.9	1.15	.59	.47	.52
	5.7	1.64	3.00	2.330	.260	.170	2.5	1.7	1.23	.46	.40	.53

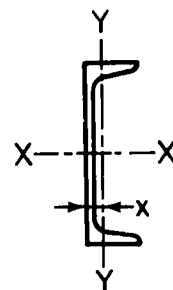


Table 14-14. American Standard Channels

Nominal size In.	Weight per foot Lb.	Area In.	Depth In.	Flange		Web Thick- ness In.	Axis X-X			Axis Y-Y			
				Width In.	Average thickness In.		I In.	S In.	r In.	I In.	S In.	r In.	x In.
18 x 4	58.0	16.98	18.00	4.200	.625	.700	670.7	74.5	6.29	18.5	5.6	1.04	0.88
	51.9	15.18	18.00	4.100	.625	.600	622.1	69.1	6.40	17.1	5.3	1.06	.87
	45.8	13.38	18.00	4.000	.625	.500	573.5	63.7	6.55	15.8	5.1	1.09	.89
	42.7	12.48	18.00	3.950	.625	.450	549.2	61.0	6.64	15.0	4.9	1.10	.90
15 x 3½	50.0	14.64	15.00	3.716	.650	.716	401.4	53.6	5.24	11.2	3.8	.87	.80
	40.0	11.70	15.00	3.520	.650	.520	346.3	46.2	5.44	9.3	3.4	.89	.78
	33.9	9.90	15.00	3.400	.650	.400	312.6	41.7	5.62	8.2	3.2	.91	.79
	30.0	8.79	12.00	3.170	.501	.510	161.2	26.9	4.28	5.2	2.1	.77	.68
12 x 3	25.0	7.32	12.00	3.047	.501	.387	143.5	23.9	4.43	4.5	1.9	.79	.68
	20.7	6.03	12.00	2.940	.501	.280	128.1	21.4	4.61	3.9	1.7	.81	.70
	30.0	8.80	10.00	3.033	.436	.673	103.0	20.6	3.42	4.0	1.7	.67	.65
	25.0	7.33	10.00	2.886	.436	.526	90.7	18.1	3.52	3.4	1.5	.68	.62
10 x 2½	20.0	5.86	10.00	2.739	.436	.379	78.5	15.7	3.66	2.8	1.3	.70	.61
	15.3	4.47	10.00	2.600	.436	.240	66.9	13.4	3.87	2.3	1.2	.72	.64
	20.0	5.86	9.00	2.648	.413	.448	60.6	13.5	3.22	2.4	1.2	.65	.59
	15.0	4.39	9.00	2.485	.413	.285	50.7	11.3	3.40	1.9	1.0	.67	.59
9 x 2¼	13.4	3.89	9.00	2.430	.413	.230	47.3	10.5	3.49	1.8	.97	.67	.61
	18.75	5.49	8.00	2.527	.390	.487	43.7	10.9	2.82	2.0	1.0	.60	.57
	13.75	4.02	8.00	2.343	.390	.303	35.8	9.0	2.99	1.5	.86	.62	.56
	11.5	3.36	8.00	2.260	.390	.220	32.3	8.1	3.10	1.3	.79	.63	.58
7 x 2½	14.75	4.32	7.00	2.299	.366	.419	27.1	7.7	2.51	1.4	.79	.57	.53
	12.25	3.58	7.00	2.194	.366	.314	24.1	6.9	2.59	1.2	.71	.58	.53
	9.8	2.85	7.00	2.090	.366	.210	21.1	6.0	2.72	.98	.63	.59	.55
	13.0	3.81	6.00	2.157	.343	.437	17.3	5.8	2.13	1.1	.65	.53	.52
6 x 2	10.5	3.07	6.00	2.034	.343	.314	15.1	5.0	2.22	.87	.57	.53	.50
	8.2	2.39	6.00	1.920	.343	.200	13.0	4.3	2.34	.70	.50	.54	.52
	9.0	2.63	5.00	1.885	.320	.325	8.8	3.5	1.83	.64	.45	.49	.48
	6.7	1.95	5.00	1.750	.320	.190	7.4	3.0	1.95	.48	.38	.50	.49
4 x 1½	7.25	2.12	4.00	1.720	.296	.320	4.5	2.3	1.47	.44	.35	.46	.46
	5.4	1.56	4.00	1.580	.296	.180	3.8	1.9	1.56	.32	.29	.45	.46
	6.0	1.75	3.00	1.596	.273	.356	2.1	1.4	1.08	.31	.27	.42	.46
	5.0	1.46	3.00	1.498	.273	.258	1.8	1.2	1.12	.25	.24	.41	.44
3 x 1½	4.1	1.19	3.00	1.410	.273	.170	1.6	1.1	1.17	.20	.21	.41	.44

¹ Car and Shipbuilding Channel, not an American Standard.

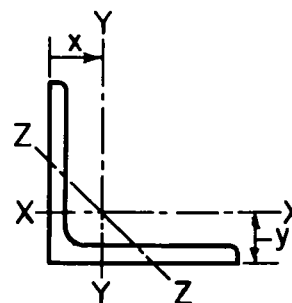


Table 14-15. Selected Angles

Size	Thick- ness	Weight per ft.-lb.	Area (sq. in.)	Axis X-X			Axis Y-Y			Axis Z-Z
				I	S	r	I	S	r	r
				Inches	Inches	Inches	Inches	Inches	Inches	Inches
8 x 8 -----	1	51.0	15.00	89.0	15.8	2.44				1.56
6 x 6 -----	7/8	33.1	9.73	31.9	7.6	1.81				1.17
5 x 5 -----	3/4	23.6	6.94	15.7	4.5	1.51	S		A	.97
4 x 4 -----	1/2	12.8	3.75	5.6	2.0	1.22	A	A	X	.78
	3/8	9.8	2.86	4.4	1.5	1.23	M	S	I	.79
	5/16	8.2	2.40	3.7	1.3	1.24	E		S	.79
3 1/2 x 3 1/2 -----	5/16	7.2	2.09	2.5	.98	1.08				.69
3 x 3 -----	5/16	6.1	1.78	1.5	.71	.92			X-X	.59
2 x 2 -----	1/4	3.19	.94	.35	.25	.61				
8 x 6 -----	3/4	33.8	9.94	63.4	11.7	2.53	30.7	6.9	1.76	1.29
6 x 4 -----	1/2	16.2	4.75	17.4	4.3	1.91	6.3	2.1	1.15	.87
	3/8	12.3	3.61	13.5	3.3	1.93	4.9	1.6	1.17	.88
5 x 3 1/2 -----	3/8	10.4	3.05	7.8	2.3	1.60	3.2	1.2	1.02	.76
	5/16	8.7	2.56	6.6	1.9	1.61	2.7	1.0	1.03	.76
5 x 3 -----	3/8	9.8	2.86	7.4	2.2	1.61	2.0	.89	.84	.65
	5/16	8.2	2.40	6.3	1.9	1.61	1.8	.75	.85	.66
4 x 3 -----	3/8	8.5	2.48	4.0	1.5	1.26	1.9	.87	.88	.64
	5/16	7.2	2.09	3.4	1.2	1.27	1.7	.73	.89	.65
3 1/2 x 3 -----	5/16	6.6	1.93	2.3	.95	1.10	1.6	.72	.90	.63

Table 14-16. Steel Pipe

Dimensions							Couplings			Properties		
Nominal diameter (inches)	Outside diameter (inches)	Inside diameter (inches)	Thick- ness (inches)	Weight per foot-pound		Threads per inch	Outside diameter (inches)	Length (inches)	Weight (pounds)	I (inches) ⁴	A (inches) ²	r (inches)
				Plain ends	Threads & cplg.							
STANDARD												
⅜ -----	0.405	0.269	0.068	0.24	0.25	27	0.562	⅞	0.03	0.001	0.072	0.12
¼ -----	.540	.364	.088	.42	.43	18	.685	1	.04	.003	.125	.16
⅝ -----	.675	.493	.091	.57	.57	18	.848	1 ⅝	.07	.007	.167	.21
½ -----	.840	.622	.109	.85	.85	14	1.024	1 ¾	.12	.017	.250	.26
¾ -----	1.050	.824	.113	1.13	1.13	14	1.281	1 ⅝	.21	.037	.333	.33
1 -----	1.315	1.049	.133	1.68	1.68	11 ½	1.576	1 ¾	.35	.087	.494	.42
1 ¼ -----	1.660	1.380	.140	2.27	2.28	11 ½	1.950	2 ⅝	.55	.195	.669	.54
1 ½ -----	1.900	1.610	.145	2.72	2.73	11 ½	2.218	2 ¾	.76	.310	.799	.62
2 -----	2.375	2.067	.154	3.65	3.68	11 ½	2.760	2 ⅝	1.23	.666	1.075	.79
2 ½ -----	2.875	2.469	.203	5.79	5.82	8	3.276	2 ¾	1.76	1.530	1.704	.95
3 -----	3.500	3.068	.216	7.58	7.62	8	3.948	3 ⅝	2.55	3.017	2.228	1.16
3 ½ -----	4.000	3.548	.226	9.11	9.20	8	4.591	3 ⅝	4.33	4.788	2.680	1.34
4 -----	4.500	4.026	.237	10.79	10.89	8	5.091	3 ⅝	5.41	7.233	3.174	1.51
5 -----	5.563	5.047	.258	14.62	14.81	8	6.296	4 ⅝	9.16	15.16	4.300	1.88
6 -----	6.625	6.065	.280	18.97	19.19	8	7.358	4 ⅝	10.82	28.14	5.581	2.25
8 -----	8.625	8.071	.277	24.70	25.00	8	9.420	4 ⅝	15.84	63.35	7.265	2.95
8 -----	8.625	7.981	.322	28.55	28.81	8	9.420	4 ⅝	15.84	72.49	8.399	2.94
10 -----	10.750	10.192	.279	31.20	32.00	8	11.721	6 ⅝	33.92	125.9	9.178	3.70
10 -----	10.750	10.136	.307	34.24	35.00	8	11.721	6 ⅝	33.92	137.4	10.07	3.69
10 -----	10.750	10.020	.365	40.48	41.13	8	11.721	6 ⅝	33.92	160.7	11.91	3.67
12 -----	12.750	12.090	.330	43.77	45.00	8	13.958	6 ⅝	48.27	248.5	12.88	4.39
12 -----	12.750	12.000	.375	49.56	50.71	8	13.958	6 ⅝	48.27	279.3	14.58	4.38
EXTRA STRONG												
⅜ -----	0.405	0.215	0.095	0.31	0.32	27	0.582	1 ⅝	0.05	0.001	0.093	0.11
¼ -----	.540	.302	.119	.54	.54	18	.724	1 ¾	.07	.004	.157	.15
⅝ -----	.675	.423	.126	.74	.75	18	.898	1 ⅝	.13	.009	.217	.20
½ -----	.840	.546	.147	1.09	1.10	14	1.085	1 ¾	.22	.020	.320	.25
¾ -----	1.050	.742	.154	1.47	1.49	14	1.316	2 ⅝	.33	.045	.433	.32
1 -----	1.315	.957	.179	2.17	2.20	11 ½	1.575	2 ¾	.47	.106	.639	.41
1 ¼ -----	1.660	1.278	.191	3.00	3.05	11 ½	2.054	2 ⅝	1.04	.242	.881	.52
1 ½ -----	1.900	1.500	.200	3.63	3.69	11 ½	2.294	2 ¾	1.17	.391	1.068	.61
2 -----	2.375	1.939	.218	5.02	5.13	11 ½	2.870	3 ⅝	2.17	.868	1.477	.77
2 ½ -----	2.875	2.323	.276	7.66	7.83	8	3.389	4 ⅝	3.43	1.924	2.254	.92
3 -----	3.500	2.900	.300	10.25	10.46	8	3.014	4 ⅝	4.13	3.894	3.016	1.14
3 ½ -----	4.000	3.364	.318	12.51	12.82	8	4.628	4 ⅝	6.29	6.280	3.678	1.31
4 -----	4.500	3.826	.337	14.98	15.39	8	5.233	4 ⅝	8.16	9.610	4.407	1.48
5 -----	5.563	4.813	.375	20.78	21.42	8	6.420	5 ⅝	12.87	20.67	6.112	1.84
6 -----	6.625	5.761	.432	28.57	29.33	8	7.482	5 ⅝	15.18	40.49	8.405	2.20
8 -----	8.625	7.625	.500	43.39	44.72	8	9.596	6 ⅝	26.63	105.7	12.76	2.88
10 -----	10.750	9.750	.500	54.74	56.94	8	11.958	6 ⅝	44.16	211.9	16.10	3.53
12 -----	12.750	11.750	.500	65.42	68.02	8	13.958	6 ⅝	51.99	361.5	19.24	4.34

Table 14-17. *Weights and Areas of Bars and Plates*

Size or thickness (inches)		Square and round bars				Plates 1 foot wide	
		Weight (pounds per foot)		Area (square inches)		Weight (pounds per foot)	Area (square inches)
		Square	Round	Square	Round		
1/4		0.213	0.167	0.0625	0.0491	10.20	3.00
3/8		.478	.376	.1406	.1105	15.30	4.50
1/2		.850	.668	.2500	.1963	20.40	6.00
5/8		1.328	1.403	.3906	.3068	25.50	7.50
3/4		1.913	1.502	.5625	.4418	30.60	9.00
7/8		2.603	2.044	.7656	.6013	35.70	10.50
1		3.400	2.670	1.0000	.7854	40.80	12.00
1 1/8		4.303	3.380	1.2656	.9940	45.90	13.50
1 1/4		5.313	4.172	1.5625	1.2272	51.00	15.00
1 1/2		7.650	6.008	2.2500	1.7671	61.20	18.00
2		13.600	10.681	4.00	3.1416	81.60	24.00
2 1/2		21.250	16.690	6.25	4.9087	102.00	30.00
3		30.600	24.033	9.00	7.0686	122.40	36.00
3 1/2		41.65	32.71	12.25	9.621	142.80	42.00
4		54.40	42.73	16.00	12.566	163.20	48.00
Size or thickness							
(millimeters)	(inches)						
5	0.20	.136	.103	.04	.03	7.990	2.35
6	.24	.204	.149	.06	.05	9.622	2.83
7	.28	.272	.203	.08	.06	11.254	3.31
8	.32	.340	.265	.10	.08	12.852	3.78
10	.39	.544	.415	.16	.12	16.082	4.73
12	.47	.748	.597	.22	.17	19.244	5.66
14	.55	1.020	.813	.30	.24	22.474	6.61
16	.63	1.258	1.062	.37	.31	25.704	7.56
18	.71	1.700	1.344	.50	.40	28.934	8.51
20	.79	2.108	1.660	.62	.49	32.096	9.44
22	.87	2.550	2.003	.75	.59	35.326	10.39
24	.94	3.026	2.386	.89	.69	38.556	11.34
26	1.02	3.570	2.802	1.05	.82	42.602	12.53
28	1.10	4.148	3.246	1.22	.95	44.948	13.22
30	1.18	4.760	3.730	1.40	1.09	48.178	14.17
32	1.26	5.406	4.240	1.59	1.25	51.408	15.12
34	1.34	6.086	4.791	1.79	1.41	54.638	16.07
36	1.42	6.834	5.369	2.01	1.58	57.800	17.00
38	1.50	7.616	5.981	2.24	1.77	61.030	17.95
40	1.57	8.432	6.633	2.48	1.94	64.260	18.90
45	1.77	10.676	8.400	3.14	2.46	72.284	21.26
50	1.97	13.192	10.349	3.88	3.05	80.342	23.63

Section IV. REINFORCED CONCRETE

14-19. Introduction

The design of a concrete structure in a theater of operations may include anything from a simple slab structure to a prestressed concrete bridge. This section is intended to give the reference for use by the engineer officers in combat and construction battalions. For a more detailed presentation, refer to TM 5-742.

14-20. Properties of Concrete

a. Strength. Concrete is used to resist com-

pressive load. The shear strength of concrete is also large, varying from 35% to 80% of the compressive strength. The tensile strength of concrete is considered minimal, and reinforcing steel is used to resist the tension. The principal influencing factor on strength is the ratio of water to cement usually stated as gallons per sack in Army troop construction. See figure 14-15.

b. Durability. Durability is the ability of concrete to resist weathering action, chemical attack,

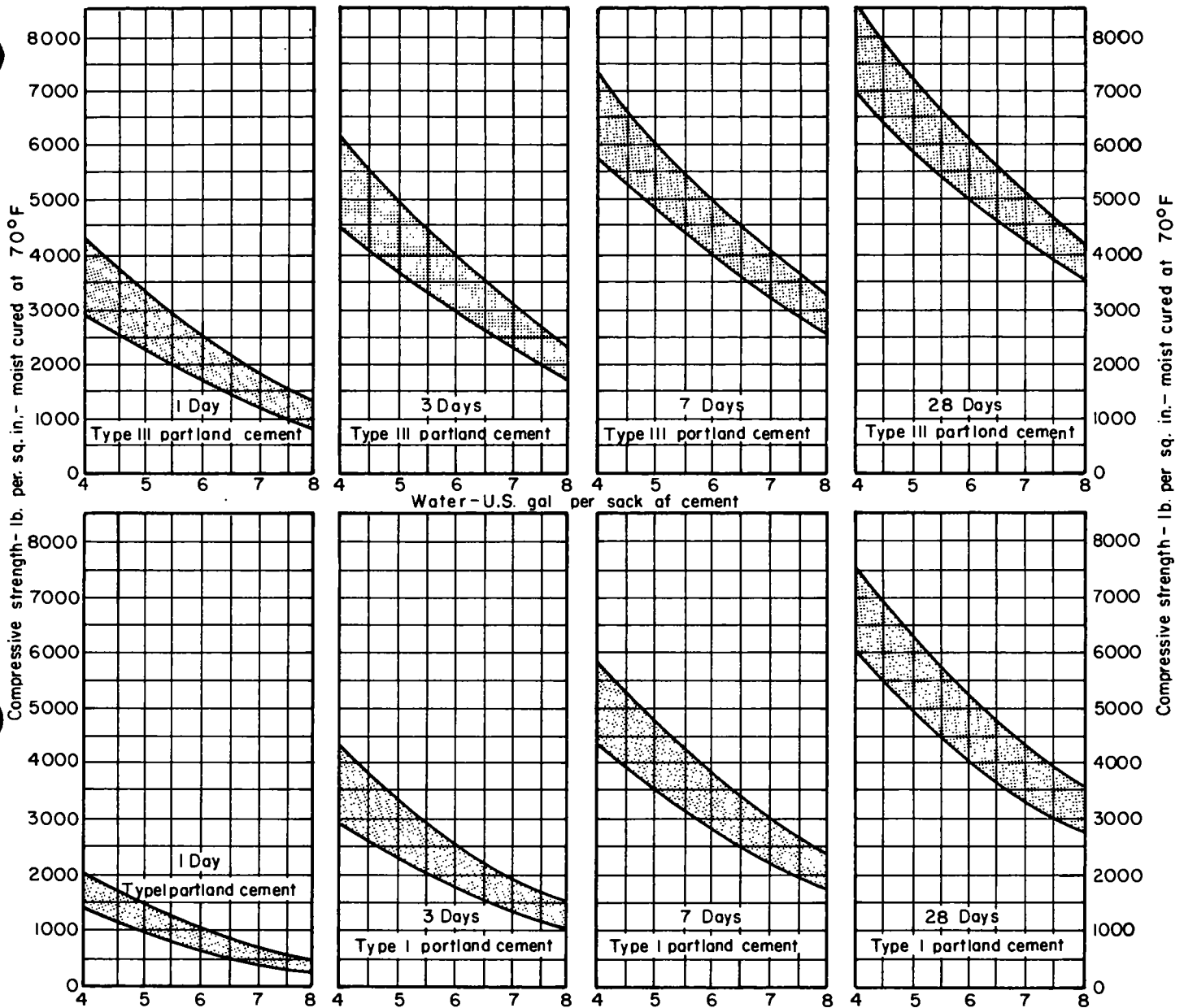


Figure 14-15. Age-compressive strength relationships for types I and III portland cement.

abrasion, and other conditions of service. This property is also affected by the W/C (water-cement) ratio. As the W/C ratio is increased, the durability will decrease correspondingly. See table 14-18.

c. Water Tightness. Water tightness is an essential requirement, which depends on the W/C ratio. To insure water tightness the W/C ratio should not exceed 6 gallons of water per sack of cement.

d. Workability. Workability is that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished.

Workability is governed primarily by the amount of aggregate mixed into a given amount of cement paste.

14-21. Mix Proportioning

a. Economy. Concrete mixtures should be designed to give the most economical and practical combination of the materials that will produce the necessary workability in the fresh concrete and the required strength, durability and water-tightness in the hardened concrete.

b. Factors in Selection of Water-Cement Ratio. Since most of the desired properties of hardened

Table 14-18. Water-Cement Ratios for Various Types of Construction and Exposure Conditions

Type of structures	Exposure conditions ¹					
	Severe wide range in temperature or frequent alternations of freezing and thawing (air-entrained concrete only) (gallons/sack)			Mild temperature rarely below freezing, or rainy, or arid (gallons/sack)		
	In air	At water line or within range of fluctuating water level or spray		In air	At water line or within range of fluctuating water level or spray	
		In fresh water	In sea water or in contact with sulfates ²		In fresh water	In sea water or in contact with sulfates
A. Thin sections such as reinforced piles and pipe	5.5	5	4.5	6	5.5	4.5
B. Bridge decks	5	5	4.5	5.5	5.5	5
C. Thin sections such as railing, curbs, sills, ledges, ornamental or architectural concrete, and all sections with less than 1-in. concrete cover over reinforcement	5.5			6	5.5	
D. Moderate sections, such as retaining walls, abutments, piers, girders, beams	6	5.5	5	†	6	5
E. Exterior portions of heavy (mass) sections	6.5	5.5	5	†	6	5
F. Concrete deposited by tremie under water		5	5		5	5
G. Concrete slabs laid on the ground	6			†		
H. Pavements	5.5			6		
I. Concrete protected from the weather, interiors of buildings, concrete below ground	†			†		
J. Concrete which will later be protected by enclosure or backfill but which may be exposed to freezing and thawing for several years before such protection is offered	6			†		

¹ Air-entrained concrete should be used under all conditions involving severe exposure and may be used under mild exposure conditions to improve workability of the mixture.

² Soil or groundwater containing sulfate concentrations of more than 0.2 per cent. For moderate sulfate resistance, the tricalcium aluminate content of the cement should be limited to 8 percent, and for high-sulfate resistance to 5 per cent. At equal cement contents, air-entrained concrete is significantly more resistant to sulfate attack than non-air-entrained concrete.

†Water-cement ratio should be selected on basis of strength and workability requirements, but minimum cement content should not be less than 470 lb. per cubic yard.

concrete are dependent upon the quality of the cement paste, the first step in proportioning a concrete mix is the selection of the appropriate water-cement ratio. The selected water-cement ratio will vary somewhat depending upon the most important quality of the hardened concrete. Table 14-18 can be used for selecting a water-cement ratio for durability for different type structures and various exposure conditions. Quantities shown are the recommended maximum permissible water-cement ratios. Figure 14-15 can be used for selecting water-cement ratio when compressive strength is the governing factor. If flexural strength governs, a relationship between compressive strength and flexural strength can be obtained by use of the formula:

$$f_c' = \left(\frac{R}{K} \right)^2$$

Where:

f_c' = compressive strength in pounds per square inch

R = flexural strength (modulus of rupture) in pounds per square inch

K = a constant, usually between 8 and 10.

c. Selection of Aggregates.

(1) The most commonly used aggregates are sand, gravel, crushed stone, and blast furnace slags. Aggregates should be clean and free of silt, clay, or chemicals. The fineness or coarseness of aggregate is measured by the fineness modulus. In general, fine aggregate with a very high or very low value for fineness modulus should be avoided. See table 14-19 for computation of fineness modulus.

(2) Gradation requirements for fine aggregates are shown in table 14-20. Fine aggregates fill the spaces in the coarse aggregate and increase the workability of the mix.

(3) The maximum size aggregate should not exceed one-fifth the minimum dimension of the member, or three-quarters the clear space between reinforcing bars. For pavement or concrete slabs, the maximum size should not exceed one-third the thickness.

d. Consistency of Concrete. The slump test is used as a measure of consistency. The slump or consistency is governed primarily by the amount of aggregate added to the mix. Acceptable slump ranges are indicated by table 14-21.

Table 14-19. Fineness Modulus

Screen size	Weight retained		Cumulative % retained
	Individual	Cumulative	
No. 4	40	40	4.0
No. 8	130	170	17.0
No. 16	130	300	30.0
No. 30	250	550	55.0
No. 50	270	820	82.0
No. 100	100	920	92.0
PAN	82	---	---
Total weight	1000	---	280.0

$$\text{Fineness modulus (FM)} = \frac{280}{100} = 2.80$$

Note: The fineness modulus values are interpreted as follows:

Fine sand	2.20-2.60
Medium sand	2.60-2.90
Coarse sand	2.90-3.20

Table 14-20. Gradation Requirements for Fine Aggregates*

Sieve size	Percent (by weight) passing sieves (square openings)
3/8 inch	100
No. 4	95-100
No. 8	80-100
No. 16	50-85
No. 30	25-60
No. 50	10-30
No. 100	2-10

*From tentative specifications for concrete aggregate (ASTM C-33-61T).

Table 14-21. Slump Values*

Type of construction	Slump, inches	
	Maximum	Minimum
Reinforced foundation walls and footings	6	3
Unreinforced footings, caissons, and substructure walls	4	1
Reinforced slabs, beams, and walls	6	3
Building columns	6	4
Pavements	3	1
Heavy mass construction	3	1
Bridge decks	4	3
Sidewalk, driveway, and slabs on ground	6	3

*When high-frequency vibrators are used the values may be decreased approximately one-third. In no case should the slump exceed 6 inches.

e. Mix Proportions. Knowing the W/C ratio, slump, fineness modulus, and the maximum size of coarse aggregate, tables of trial mixes (table 14-22) can be used to obtain the weights of materials and the yield.

f. Estimate of Material.

(1) *Loss factor.* Handling loss factors of 5% for jobs requiring 200 or more cubic yards and 10% for smaller jobs are added when ordering materials.

(2) *1:2:3 ratio and 3/2 rule.* When tables such as table 14-22 are not available a mix ratio of 1:2:3 can be assumed as a start. The W/C ratio should be assumed to be 6 to assure water tightness. To produce a given volume of concrete, the 3/2 rule states that the combined amounts of cement, sand, and gravel are 3/2 times the volume.

(3) *Example problem.* Using the 3/2 rule and 1:2:3 ratio, determine amounts of cement, sand, and gravel required to construct a 20' x 100' x 1' maintenance shop pad.

Solution. Volume of concrete:

$$20 \times 100 \times 1 = 2000 \text{ cu ft} \\ = 74.1 \text{ cu yd}$$

Apply 3/2 rule and the 10% loss factor

$$\text{Total volume required} = \frac{3}{2} \times 1.10 \times 74.1 \\ = 122.3 \text{ cu yd}$$

The required volumes needed are—

$$\text{cement: } \frac{1}{6} \times 122.3 = 20.4 \text{ cu yd}$$

$$\text{sand: } \frac{2}{6} \times 122.3 = 40.8 \text{ cu yd}$$

$$\text{gravel: } \frac{3}{6} \times 122.3 = 61.2 \text{ cu yd}$$

Since cement is usually obtained in sacks containing 1 cubic foot of cement, multiply the cement volume by 27 to find number of sacks.

$$20.4 \times 27 = 551 \text{ sacks}$$

14-22. Principles of Reinforcing

a. Reinforced Concrete. Concrete is strong in compression, but relatively weak in tension. The reverse is true for slender steel bars and when the two materials are used together one makes up for the deficiency of the other. When steel is embedded in concrete in a manner which assists it in carrying imposed loads, the combination is known as reinforced concrete. Beam strength can be increased significantly by the use of steel in the tension side (fig. 14-16).

b. Bond Strength. Bond strength is the resistance developed by concrete to the pulling out of a steel bar embedded therein. The theory of reinforced concrete beam design is based on the assumption that a bond exists between the steel and concrete which prevents relative movement

Table 14-22. Suggested Trial Mixes for Concrete of Medium Consistency With a 3-Inch Slump* (SSD Condition)

Maximum size of aggregate, inches	Water, gallon per sack of cement	Water, gallon per cu yd of concrete	Cement, sacks per cu yd of concrete	Fine aggregate—per cent of total aggregate	Fine aggregate—lb per sack of cement	Coarse aggregate—lb per sack of cement	Fine aggregate—lb per cu yd of concrete	Coarse aggregate—lb per cu yd of concrete	Yield, cu ft concrete per sack of cement	Fine aggregate—per cent of total aggregate	Fine aggregate—lb per sack of cement	Coarse aggregate—lb per sack of cement	Fine aggregate—lb per cu yd of concrete	Coarse aggregate—lb per cu yd of concrete	Yield, cu ft concrete per sack of cement	Fine aggregate—per cent of total aggregate	Fine aggregate—lb per sack of cement	Coarse aggregate—lb per sack of cement	Fine aggregate—lb per cu yd of concrete	Coarse aggregate—lb per cu yd of concrete	Yield, cu ft concrete per sack of cement
				With Fine Sand—Fineness Modulus 2.20-2.60						With Medium Sand—Fineness Modules 2.60-2.90						With Coarse Sand—Fineness Modulus 2.90-3.20					
¾	5	38	7.6	43	170	230	1290	1750	3.56	45	180	220	1370	1670	3.56	47	185	210	1370	1595	3.56
1	5	37	7.4	38	160	255	1185	1890	3.65	40	165	250	1220	1850	3.65	42	175	240	1295	1775	3.65
1½	5	35	7.0	34	150	300	1050	2100	3.86	36	160	290	1120	2030	3.86	38	170	280	1190	1960	3.86
2	5	33	6.6	31	150	335	990	2210	4.09	33	160	325	1055	2140	4.09	35	170	315	1120	2080	4.09
¾	5½	38	6.9	44	195	250	1345	1725	3.91	46	205	240	1415	1655	3.91	48	215	230	1480	1585	3.91
1	5½	37	6.7	39	180	285	1205	1910	4.03	41	190	275	1270	1840	4.03	43	200	265	1340	1775	4.03
1½	5½	35	6.4	35	175	320	1120	2050	4.22	37	185	315	1185	2015	4.22	39	195	305	1250	1950	4.22
2	5½	33	6.0	32	175	370	1050	2220	4.50	34	185	360	1110	2160	4.50	36	195	350	1170	2100	4.50
¾	6	38	6.3	45	225	275	1420	1730	4.29	47	235	265	1480	1670	4.29	49	245	255	1540	1610	4.29
1	6	37	6.2	40	205	305	1270	1890	4.36	42	215	295	1335	1830	4.36	44	225	285	1395	1770	4.36
1½	6	35	5.8	36	200	355	1160	2060	4.66	38	210	345	1220	2000	4.66	40	225	335	1305	1945	4.66
2	6	33	5.5	33	200	400	1100	2200	4.91	35	210	390	1155	2145	4.91	37	220	380	1210	2090	4.91
¾	6½	38	5.9	46	245	288	1445	1700	4.58	48	255	280	1505	1650	4.58	50	265	265	1560	1560	4.58
1	6½	37	5.7	41	230	330	1310	1880	4.74	43	240	320	1370	1825	4.74	45	250	310	1425	1765	4.74
1½	6½	35	5.4	37	225	380	1215	2050	5.00	39	235	370	1270	2000	5.00	41	250	355	1350	1920	5.00
2	6½	33	5.1	34	225	430	1150	2195	5.30	36	235	415	1200	2120	5.30	38	250	405	1275	2065	5.30
¾	7	38	5.4	47	280	315	1510	1700	5.00	49	290	305	1565	1650	5.00	51	300	290	1620	1565	5.00
1	7	37	5.3	42	255	355	1350	1880	5.10	44	270	340	1430	1800	5.10	46	280	330	1485	1750	5.10
1½	7	35	5.0	38	250	410	1250	2050	5.40	40	265	395	1325	1975	5.40	42	270	385	1350	1925	5.40
2	7	33	4.7	35	250	465	1175	2185	5.75	37	265	450	1245	2120	5.75	39	280	435	1315	2045	5.75
¾	7½	38	5.1	48	300	330	1530	1680	5.30	50	315	315	1605	1605	5.30	52	330	300	1685	1530	5.30
1	7½	37	4.9	43	285	380	1400	1860	5.51	45	300	365	1470	1790	5.51	47	310	355	1520	1740	5.51
1½	7½	35	4.7	39	275	430	1290	2020	5.75	41	290	415	1365	1950	5.75	43	305	400	1435	1880	5.75
2	7½	33	4.4	36	275	495	1210	2180	6.14	38	290	480	1275	2110	6.14	40	305	465	1340	2045	6.14
¾	8	38	4.8	49	330	345	1585	1655	5.63	51	345	330	1660	1585	5.63	53	360	315	1730	1510	5.63
1	8	37	4.6	44	315	400	1450	1840	5.87	46	330	385	1520	1770	5.87	48	345	370	1590	1700	5.87
1½	8	35	4.4	40	305	455	1340	2000	6.14	42	320	440	1410	1935	6.14	44	335	425	1475	1870	6.14
2	8	33	4.1	37	310	525	1270	2150	6.59	39	325	510	1330	2090	6.59	41	340	490	1395	2010	6.59

*Increase or decrease water per cu. yd. of concrete by 3% for each increase or decrease of 1 in. in slump recalculate quantities of cement and aggregate to maintain the quality of concrete. For stone sand, increase percentage of sand by 8 and water by 15 lb per cu yd of

concrete. For less workable concrete, as in pavements, decrease percentage of sand by 8 and water by 8 lb per cu yd of concrete.

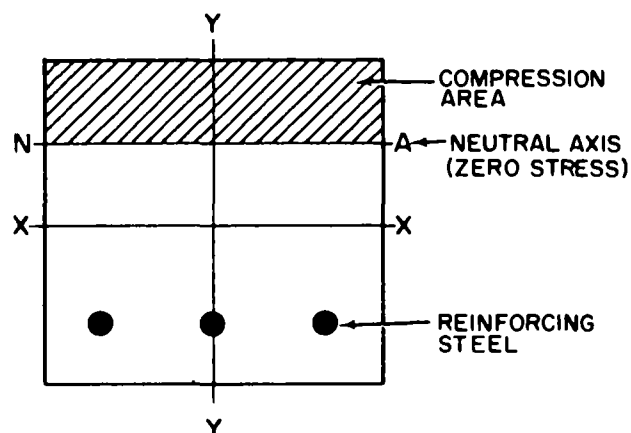


Figure 14-16. Cross section of a reinforced concrete beam.

between them as the load is applied. The amount of bond strength that can be developed depends largely upon the area of contact between the two materials. Due to their superior bond value, bars manufactured with a very rough outside surface, called deformed bars (fig 14-17), have replaced plain bars. Table 14-23 gives dimensions and weights of standard deformed reinforcing bars.

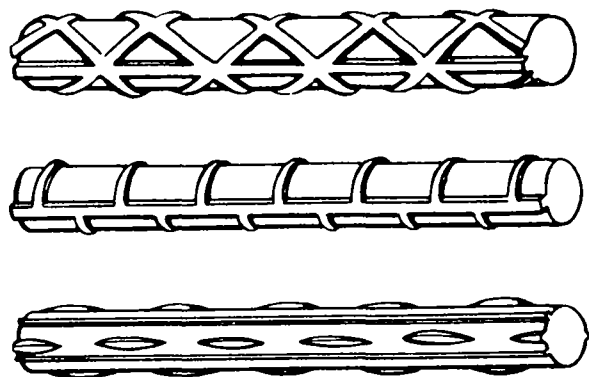
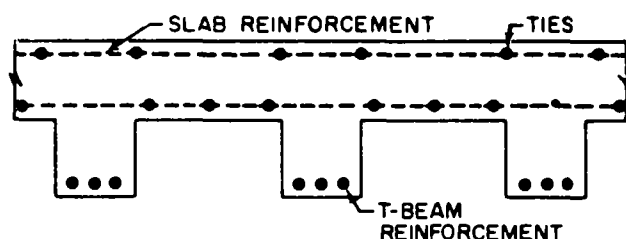


Figure 14-17. Steel reinforcing bars.

c. *Bending Strength.* When a beam is subjected to a bending moment it deflects because the parts that are in compression shorten and those that are in tension become longer. The weak portions of the beam as shown by the short irregular lines (fig 14-18), where tension exists, must be reinforced with steel. This figure is not intended to show that beams always crack excessively, but to show the condition that beams may reach if they are loaded sufficiently. Concrete in the areas subjected to compression is usually effective by itself.

1. REINFORCEMENT



2. EFFECTS OF VERTICAL LOAD

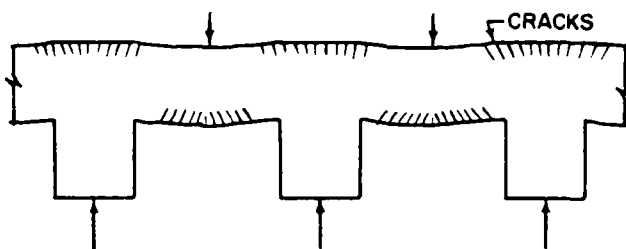


Figure 14-18. Concrete beam.

d. *Design.* The term "design of a beam" denotes determination of the size and the materials required to construct a beam that can safely support specified loads under certain definite conditions of span, stress, and the like. Economy and efficiency in the use of materials, strength,

Table 14-23. ASTM A615 Standard Deformed Reinforcing Bars*

Designation Bar No. **	Unit Weight lb/ft.	Diameter in.	Cross-sectional Area, in. ²	Perimeter in.
3	.376	0.375	0.11	1.178
4	.668	0.500	0.20	1.571
5	1.043	0.625	0.31	1.963
6	1.502	0.750	0.44	2.356
7	2.044	0.875	0.60	2.749
8	2.670	1.000	0.79	3.142
9	3.400	1.128	1.00	3.544
10	4.303	1.270	1.27	3.990
11	5.313	1.410	1.56	4.430
14	7.65	1.693	2.25	5.32
18	13.60	2.257	4.00	7.09

*The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.

**Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.

spacing, and arrangement of reinforcing steel are factors which enter into the design. The design of a reinforced concrete structure requires sound engineering judgment and experience. No attempt is made to present reinforced concrete design formulas in this manual in view of the many authoritative texts available in this field.

e. Workmanship. It is emphasized that the best of designs can be ruined if the intent of the plan is not carried out faithfully and intelligently in the field. Proper reinforced concrete construction depends upon supervision by personnel who understand the action of structures

and who understand thoroughly the characteristics and limitations of the material.

14-23. Retaining Walls

For average earth pressures and for heights up to 10 feet, some suggested cross sections for plain and reinforced concrete retaining walls are given in figure 14-19.

14-24. Forms and Braces

Figures 14-20 through 14-24 provide information useful in the design of concrete forms.

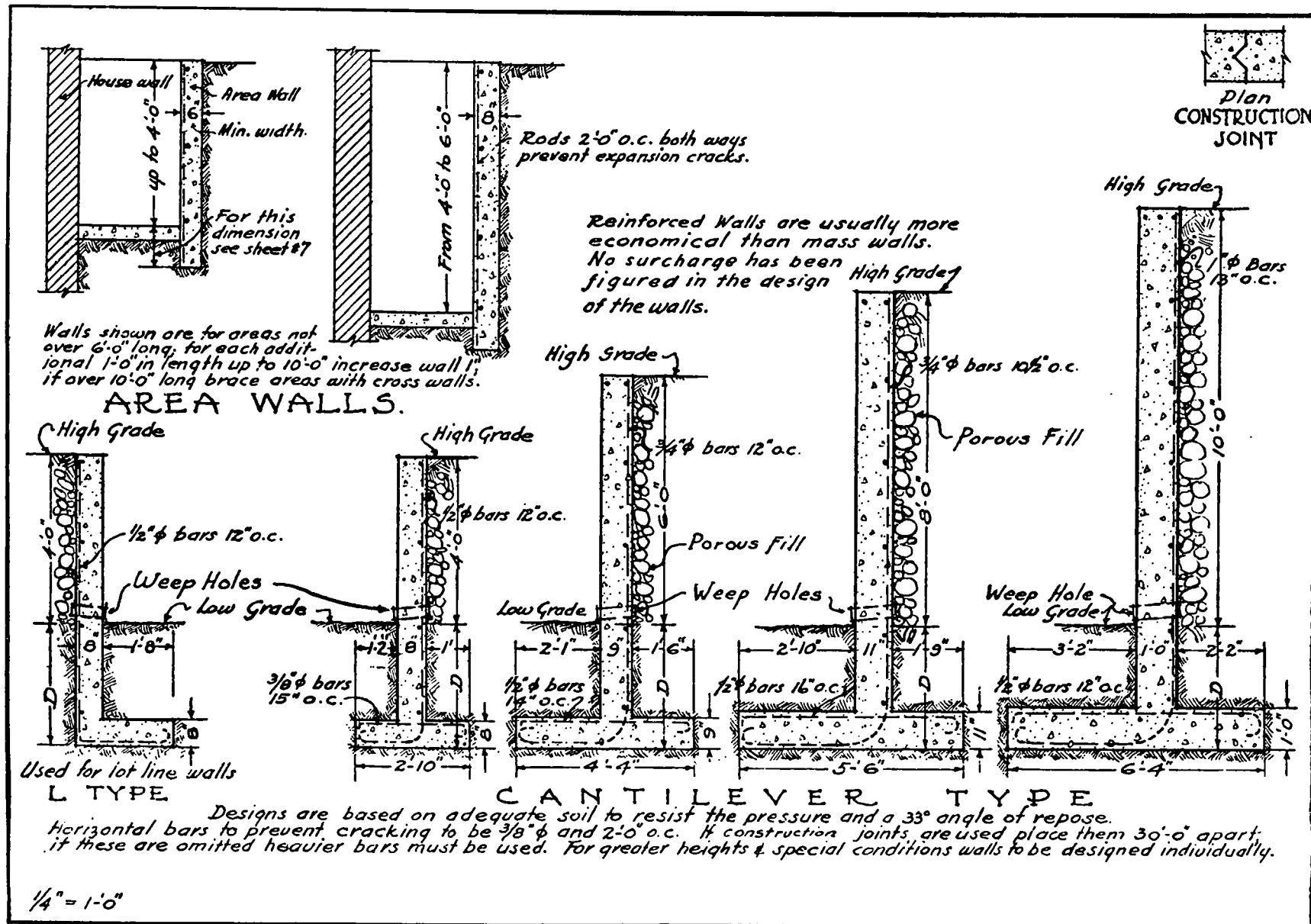


Figure 14-19. Concrete retaining walls.

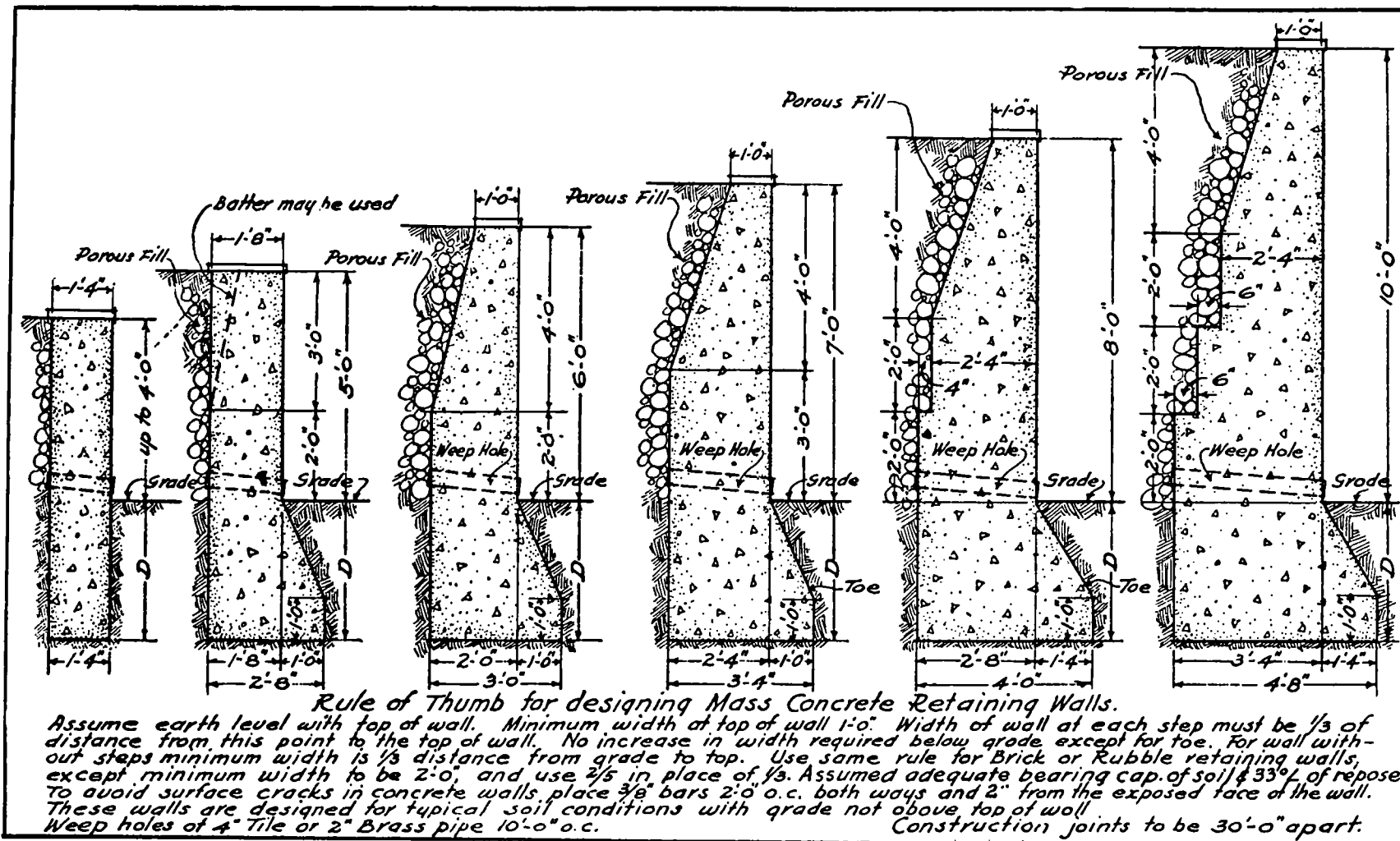


Figure 14-19. Concrete retaining walls—Continued.

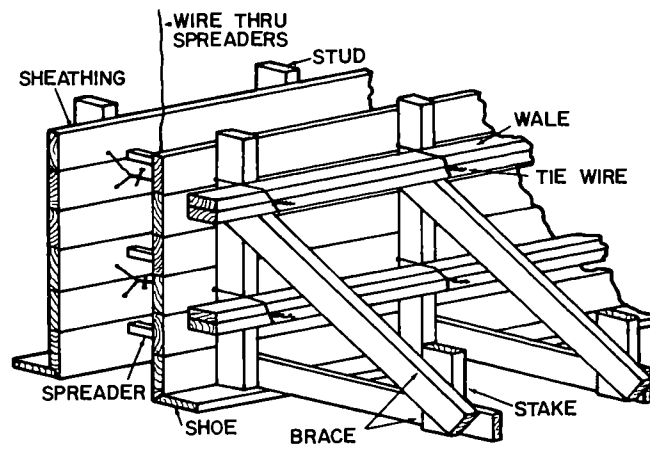


Figure 14-20. Form for a concrete wall.

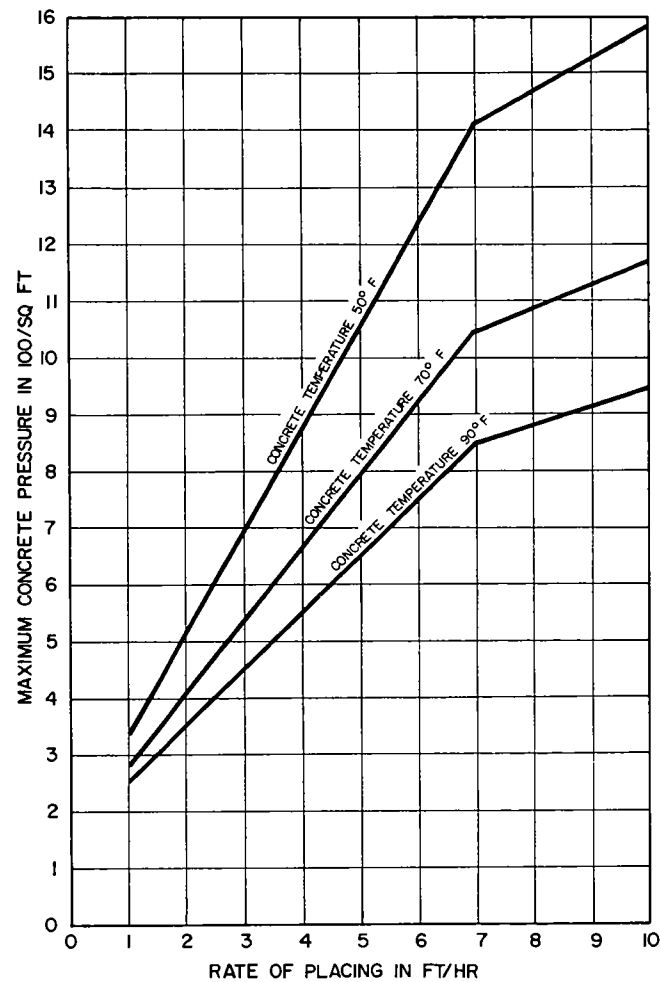
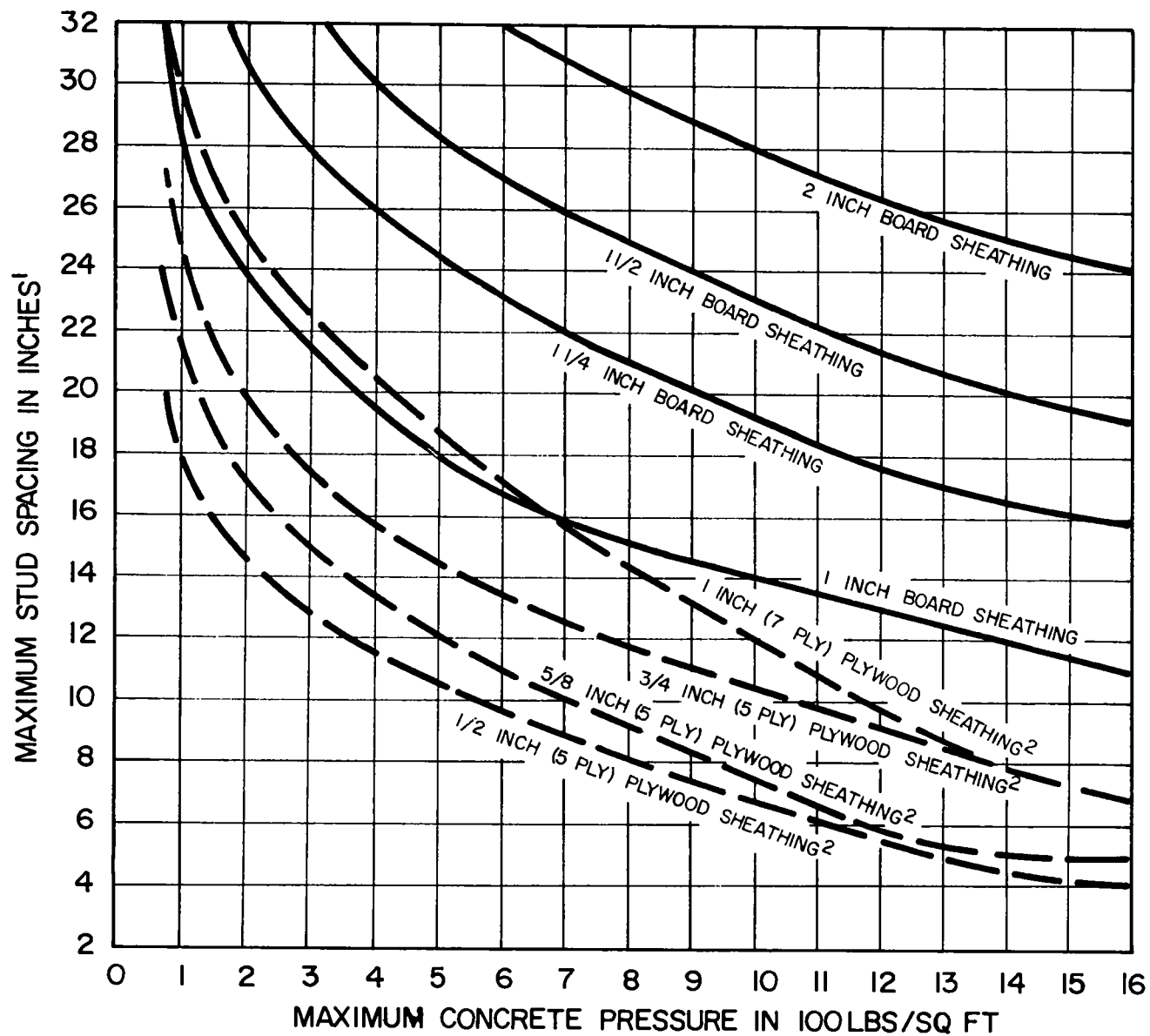


Figure 14-21. Maximum concrete pressure graph.



¹ MAXIMUM ALLOWABLE STUD SPACING = 32 INCHES

² SANDED FACE GRAIN PARALLEL TO SPAN

Figure 14-22. Maximum stud spacing graph.

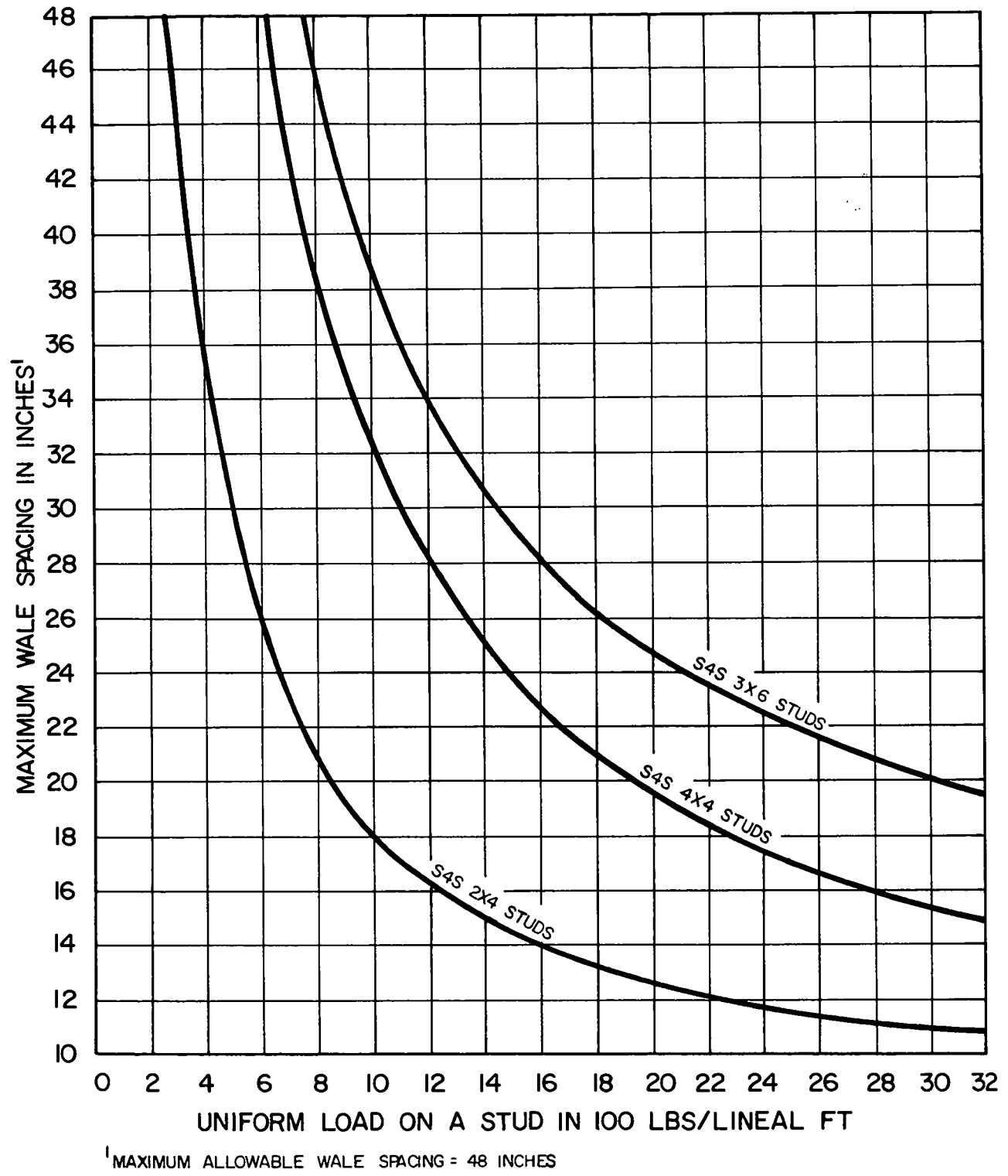


Figure 14-23. Maximum wale spacing graph.

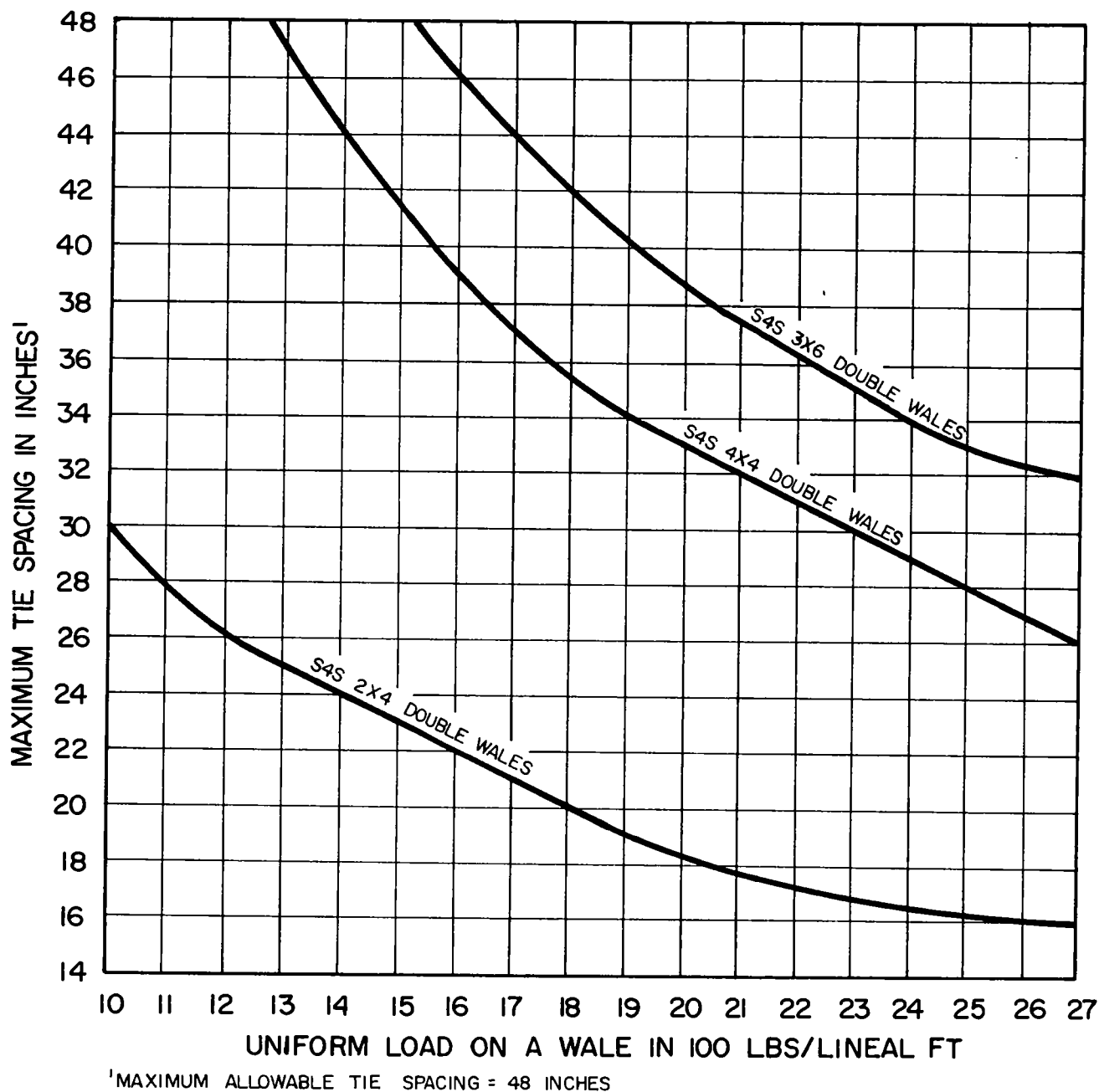


Figure 14-24. Maximum tie wire spacing.

Section V. TIMBER

14-25. Introduction

a. Grain. The term grain is used to describe the spacing and orientation of growth rings.

(1) *Edge grain.* Lumber in which the growth rings are at approximately right angles with the surface of the lumber. The rings form an angle of at least 45° with the face.

(2) *Flat grain.* Lumber in which the face is approximately tangent to the growth rings. The rings form an angle less than 45° with the surface.

(3) *Close, medium, and coarse grain.* Close grain, medium grain, and coarse grain refer to width and spacing of the annual growth rings. It has to do with the texture of the wood.

(4) *Cross grain.* Cross grain is a deviation of the direction of the fibers of the wood from a line parallel to the edges of the piece. Its measurement, called slope of grain, is the deviation of the line of the fibers over the distance on which the deviation occurs.

b. Classification of Structural Lumber.

(1) *Beams and stringers.* Lumber of rectangular cross section, 5 or more inches thick and 8 or more inches wide, graded with respect to its strength in bending when loaded on the narrow face.

(2) *Joists and planks.* Lumber of rectangular cross section, 2 inches to, but not including 5 inches thick, and 4 or more inches wide, graded with respect to its strength in bending when loaded either on the narrow face as a joist or on the wide face as a plank.

(3) *Posts and timbers.* Lumber of square or approximately square cross section 5 x 5 inches and larger, graded primarily for use as posts or columns carrying longitudinal load, but adapted for miscellaneous uses in which strength in bending is not especially important.

c. Wood Preservatives.

(1) For best protection the preservatives should be injected into the wood under pressure. The penetration must reach a sufficient depth to form a protective shield, which must be stable under the service conditions.

(2) Creosote is generally used for the treatment of timber in contact with the ground and in many outdoor structures, where its odor is of little consequence and painting is not necessary.

(3) Salt treatment is used where painting

is required or where the odor or color of creosote may be objectionable.

(4) Water repellent preservatives are usually applied by dipping, brushing, or spraying. They also retard the adsorption of moisture and thus minimize dimensional changes. They are especially useful when used above the ground where the lumber is dry most of the time or where a painted surface is desired.

d. Fire Resistance.

(1) Wood does not lose strength when exposed to heat. It weakens only when in direct contact with a continuous hot flame, through a gradual reduction in cross-sectional area. Wood continues to act as a support even after its section has been considerably reduced in size, thus eliminating the possibility of sudden collapse. In the presence of continued high temperature, it chars progressively and this insulates the inner layers of wood against increased temperature.

(2) Wood is impregnated with fire-retardant chemicals by the same vacuum-pressure methods used in injecting wood preservatives. The most common chemicals are ammonium sulphate, ammonium phosphate, and zinc chloride.

(3) Coatings are neither as effective nor as durable as impregnation treatments. Good fire-retarding paints, however, may be effective in controlling small fires and can be applied to the surfaces of timbers already in a structure. Cold-water paints, including sodium silicate, white-wash and some casein products, are among the most effective fire-retardant coatings.

14-26. Allowable Unit Stresses

Table 14-24 gives allowable unit stresses for the various species of lumber.

Table 14-24. Allowable Unit Stresses—Stress-Grade Lumber

1 Species and commercial grade ¹	2 Rules under which graded	Allowable unit stresses in pounds per square inch				7 Modulus of elasticity "E"
		3 Extreme fiber in bending "f" and tension parallel to grain "t"	4 Horizontal shear "H"	5 Compression perpendicular to grain "c1"	6 Compression parallel to grain "c"	
CEDAR, INCENSE						
Select Dex ¹⁰	Decking	1,100	-----	305	-----	990,000
Commercial Dex ¹⁰	Decking	850	-----	305	-----	990,000
		West Coast Lumber Inspection Bureau				

See notes below table.

Table 14-24. Allowable Unit Stresses—Stress-Grade Lumber—Continued

1 Species and commercial grade ¹		2 Rules under which grade	Allowable unit stresses in pounds per square inch				7 Modulus of elasticity "E"
			3 Extreme fiber in bending "f" and tension parallel to grain "t"||	4 Horizontal shear "H"	5 Compression perpendicular to grain "c" _⊥	6 Compression parallel to grain "c"	
CEDAR, INCENSE & WESTERN RED							
Select Decking ¹⁰ -----	Decking -----	Western Pine	900	-----	240	-----	1,100,000
Commercial Decking ¹⁰ -----	Decking -----	Association.	700	-----	240	-----	1,100,000
CEDAR, WESTERN RED							
Select Dex ¹⁰ -----	Decking -----	West Coast	900	-----	240	-----	1,100,000
Commercial Dex ¹⁰ -----	Decking -----	Lumber In- spection Bu- reau.	700	-----	240	-----	1,100,000
DOUGLAS FIR, COAST REGION							
Dense Select Structural ² -----	L.F -----	West Coast Lumber In- spection Bu- reau.	2,050	^{5 8 8} 120	455	1,500	1,760,000
Select Structural -----	L.F -----		1,900	^{5 8 8} 120	415	1,400	1,760,000
1500 f Industrial -----	L.F -----		1,500	120	390	1,200	1,760,000
1200 f Industrial -----	L.F -----		1,200	95	390	1,000	1,760,000
Dense Select Structural ² -----	J.&P -----		2,050	^{5 8 8} 120	455	1,650	1,760,000
Select Structural -----	J.&P -----		1,900	^{5 8 8} 120	415	1,500	1,760,000
Dense Construction ² -----	J.&P -----		1,750	^{5 7 8} 120	455	1,400	1,760,000
Construction -----	J.&P -----		1,500	^{5 7 8} 120	390	1,200	1,760,000
Standard -----	J.&P -----		1,200	^{5 7 8} 95	390	1,000	1,760,000
Dense Select Structural ² -----	B.&S -----		2,050	⁹ 120	455	1,500	1,760,000
Select Structural -----	B.&S -----		1,900	⁹ 120	415	1,400	1,760,000
Dense Construction ² -----	B.&S -----		1,750	⁹ 120	455	1,200	1,760,000
Construction -----	B.&S -----		1,500	⁹ 120	390	1,000	1,760,000
Dense Select Structural ² -----	P.&T -----		1,900	⁹ 120	455	1,650	1,760,000
Select Structural -----	P.&T -----		1,750	⁹ 120	415	1,500	1,760,000
Dense Construction ² -----	P.&T -----		1,500	⁹ 120	455	1,400	1,760,000
Construction -----	P.&T -----		1,200	⁹ 120	390	1,200	1,760,000
Select Dex ¹⁰ -----	Decking -----		1,500	-----	390	-----	1,760,000
Commercial Dex ¹⁰ -----	Decking -----		1,200	-----	390	-----	1,760,000
DOUGLAS FIR							
Dense Select Structural ² -----	L.F -----	Western Pine Association.	2,050	^{5 8 8} 120	455	1,500	1,760,000
Select Structural -----	L.F -----		1,900	^{5 8 8} 120	415	1,400	1,760,000
1500 f Industrial -----	L.F -----		1,500	120	390	1,200	1,760,000
1200 f Industrial -----	L.F -----		1,200	95	390	1,000	1,760,000
Dense Select Structural ² -----	J.&P -----		2,050	^{5 8 8} 120	455	1,650	1,760,000
Select Structural -----	J.&P -----		1,900	^{5 8 8} 120	415	1,500	1,760,000
Dense Construction ² -----	J.&P -----		1,750	^{5 7 8} 120	455	1,400	1,760,000
Construction -----	J.&P -----		1,500	^{5 7 8} 120	390	1,200	1,760,000
Standard -----	J.&P -----		1,200	^{5 7 8} 95	390	1,000	1,760,000
Dense Select Structural ² -----	B.&S -----		2,050	⁹ 120	455	1,500	1,760,000
Select Structural -----	B.&S -----		1,900	⁹ 120	415	1,400	1,760,000
Dense Construction ² -----	B.&S -----		1,750	⁹ 120	455	1,200	1,760,000
Construction -----	B.&S -----		1,500	⁹ 120	390	1,000	1,760,000
Dense Select Structural ² -----	P.&T -----		1,900	⁹ 120	455	1,650	1,760,000
Select Structural -----	P.&T -----		1,750	⁹ 120	415	1,500	1,760,000
Dense Construction ² -----	P.&T -----		1,500	⁹ 120	455	1,400	1,760,000
Construction -----	P.&T -----		1,200	⁹ 120	390	1,200	1,760,000
Selected Decking ¹⁰ -----	Decking -----		1,500	-----	390	-----	1,760,000
Commercial Decking ¹⁰ -----	Decking -----		1,200	-----	390	-----	1,760,000
FIR, WHITE							
Select Dex ¹⁰ -----	Decking -----	West Coast	1,100	-----	365	-----	1,210,000

See notes below table.

Table 14-24. Allowable Unit Stresses—Stress-Grade Lumber—Continued

1 Species and commercial grade ¹		2 Rules under which grade	Allowable unit stresses in pounds per square inch				7 Modulus of elasticity "E"
			3 Extreme fiber in bending "f" and tension parallel to grain "t" ³	4 Horizontal shear "H"	5 Compression perpendicular to grain "c1"	6 Compression parallel to grain "c"	
Commercial Dex ¹⁰	Decking	Lumber Inspection Bureau.	850	-----	365	-----	1,210,000
FIR, WHITE							
Selected Decking ¹⁰	Decking	Western Pine	1,100	-----	365	-----	1,210,000
Commercial Decking ¹⁰	Decking	Association.	850	-----	365	-----	1,210,000
HEMLOCK, EASTERN							
Select Structural	J.&P. ⁴ B.&S. ⁴ ..	Northern	1,300	85	360	850	1,210,000
Prime Structural	J.&P. ¹⁴	Hardwood &	1,200	60	360	775	1,210,000
Common Structural	J.&P. ¹⁴	Pine Mfrs.	1,100	60	360	650	1,210,000
Utility Structural	J.&P. ¹⁴	Association.	950	60	360	600	1,210,000
Select Structural	P.&T		-----	-----	360	850	1,210,000
HEMLOCK, WEST COAST							
Select Structural	L.F	West Coast	1,600	^{5 8 12} 100	365	1,100	1,540,000
1500 f Industrial	L.F		1,500	100	365	1,000	1,540,000
1200 f Industrial	L.F		1,200	80	365	900	1,540,000
Select Structural	J.&P	Lumber Inspection Bureau.	1,600	^{5 8 12} 100	365	1,200	1,540,000
Construction	J.&P		1,500	^{5 11 12} 100	365	1,100	1,540,000
Standard	J.&P		1,200	^{5 11 12} 80	365	1,000	1,540,000
Construction	B.&S		1,500	¹³ 100	365	1,000	1,540,000
Construction	P.&T		1,200	¹³ 100	365	1,100	1,540,000
Select Dex ¹⁰	Decking		1,300	-----	365	-----	1,540,000
Commercial Dex ¹⁰	Decking		1,000	-----	365	-----	1,540,000
HEMLOCK, WESTERN							
Select Structural	L.F		1,600	^{5 8 12} 100	365	1,100	1,540,000
1500 f Industrial	L.F		1,500	100	365	1,000	1,540,000
1200 f Industrial	L.F		1,200	80	465	900	1,540,000
Select Structural	J.&P	Western Pine Association.	1,600	^{5 8 12} 100	365	1,200	1,540,000
Construction	J.&P		1,500	^{5 11 12} 100	365	1,200	1,540,000
Standard	J.&P		1,200	^{5 11 12} 80	365	1,000	1,540,000
Construction	B.&S		1,500	¹³ 100	365	1,000	1,540,000
Construction	P.&T		1,200	¹³ 100	365	1,100	1,540,000
Selected Decking ¹⁰	Decking		1,300	-----	365	-----	1,540,000
Commercial Decking ¹⁰	Decking		1,000	-----	365	-----	1,540,000
LARCH							
Dense Select Structural ²	L.F		2,050	^{5 8 8} 120	455	1,500	1,760,000
Select Structural	L.F		1,900	^{5 8 8} 120	415	1,400	1,760,000
1500 f Industrial	L.F		1,500	120	390	1,200	1,760,000
1200 f Industrial	L.F		1,200	95	390	1,000	1,760,000
Dense Select Structural ²	J.&P	Western Pine Association.	2,050	^{5 8 8} 120	455	1,650	1,760,000
Select Structural	J.&P		1,900	^{5 8 8} 120	415	1,500	1,760,000
Dense Construction ²	J.&P		1,750	^{5 7 8} 120	455	1,400	1,760,000
Construction	J.&P		1,500	^{5 7 8} 120	390	1,200	1,760,000
Standard	J.&P		1,200	^{5 7 8} 95	390	1,000	1,760,000
Dense Select Structural ²	B.&S		2,050	⁹ 120	455	1,500	1,760,000
Select Structural	B.&S		1,900	⁹ 120	415	1,400	1,760,000
Dense Construction ²	B.&S		1,750	⁹ 120	455	1,200	1,760,000
Construction	B.&S		1,500	⁹ 120	390	1,000	1,760,000

See notes below table.

Table 14-24. Allowable Unit Stresses—Stress-Grade Lumber—Continued

1 Species and commercial grade ¹	2 Rules under which grade	Allowable unit stresses in pounds per square inch				7 Modulus of elasticity "E"
		3 Extreme fiber in bending "f" and tension parallel to grain "t" ²	4 Horizontal shear "H"	5 Compression perpendicular to grain "c ₁ "	6 Compression parallel to grain "c"	
Dense Select Structural ³ -----	P.&T -----	1,900	* 120	455	1,500	1,760,000
Select Structural -----	P.&T -----	1,750	* 120	415	1,500	1,760,000
Dense Construction ² -----	P.&T -----	1,500	* 120	455	1,400	1,760,000
Construction -----	P.&T -----	1,200	* 120	390	1,200	1,760,000
Selected Decking ¹⁰ -----	Decking -----	1,500	-----	390	-----	1,760,000
Commercial Decking ¹⁰ -----	Decking -----	1,200	-----	390	-----	1,760,000
PINE, SOUTHERN ¹⁰						
Dense Structural 86 KD ^{2 17 18} -----	2" thick only	3,000	165	455	2,250	1,760,000
Dense Structural 72 KD ^{2 17 18} -----	do	2,500	150	455	1,950	1,760,000
Dense Structural 65 KD ^{2 17 18} -----	do	2,250	135	455	1,800	1,760,000
Dense Structural 58 KD ^{2 17 18} -----	do	2,050	120	455	1,650	1,760,000
No. 1 Dense KD ^{2 17 18} -----	do	2,050	135	455	1,750	1,760,000
No. 1 KD ¹⁷ -----	do	1,750	135	390	1,500	1,760,000
No. 2 Dense KD ^{2 17 18} -----	do	1,750	120	455	1,300	1,760,000
No. 2 KD ¹⁷ -----	do	1,500	120	390	1,100	1,760,000
Dense Structural 86 ^{2 18} -----	2" thick only	2,900	150	455	2,200	1,760,000
Dense Structural 72 ^{2 18} -----	do	2,350	135	455	1,800	1,760,000
Dense Structural 65 ^{2 18} -----	do	2,050	120	455	1,600	1,760,000
Dense Structural 58 ^{2 18} -----	do	1,750	105	455	1,450	1,760,000
No. 1 Dense ^{2 18} -----	do	1,750	120	455	1,550	1,760,000
No. 1 -----	do	1,500	120	390	1,350	1,760,000
No. 2 Dense ^{2 18} -----	do	1,400	105	455	1,050	1,760,000
No. 2 -----	do	1,200	105	390	900	1,760,000
Dense Structural 86 ^{2 18} -----	3" & 4" thick	2,900	150	455	2,200	1,760,000
Dense Structural 72 ^{2 18} -----	do	2,350	135	455	1,800	1,760,000
Dense Structural 65 ^{2 18} -----	do	2,050	120	455	1,600	1,760,000
Dense Structural 58 ^{2 18} -----	do	1,750	105	455	1,450	1,760,000
No. 1 Dense SR ^{2 18} -----	do	1,750	120	455	1,750	1,760,000
No. 1 SR -----	do	1,500	120	390	1,500	1,760,000
No. 2 Dense SR ^{2 18} -----	do	1,400	105	455	1,050	1,760,000
No. 2 SR -----	do	1,200	105	390	900	1,760,000
Dense Structural 86 ^{2 18} -----	5" thick & up	¹⁸ 2,400	150	455	1,800	1,760,000
Dense Structural 72 ^{2 18} -----	do	¹⁸ 2,000	135	455	1,550	1,760,000
Dense Structural 65 ^{2 18} -----	do	¹⁸ 1,800	120	455	1,400	1,760,000
Dense Structural 58 ^{2 18} -----	do	¹⁸ 1,600	105	455	1,300	1,760,000
No. 1 Dense SR ^{2 18} -----	do	¹⁸ 1,600	120	455	1,500	1,760,000
No. 1 SR -----	do	¹⁸ 1,400	120	390	1,300	1,760,000
No. 2 Dense SR ^{2 18} -----	do	¹⁸ 1,400	105	455	1,050	1,760,000
No. 2 SR -----	do	¹⁸ 1,200	105	390	900	1,760,000
Industrial 86 KD ¹⁷ -----	1", 1¼" and	2,600	165	390	1,950	1,760,000
Industrial 72 KD ¹⁷ -----	1½" thick	2,200	150	390	1,650	1,760,000
Industrial 65 KD ¹⁷ -----	do	2,000	135	390	1,550	1,760,000
Industrial 58 KD ¹⁷ -----	do	1,750	120	390	1,400	1,760,000
Industrial 50 KD ¹⁷ -----	do	1,500	120	390	1,100	1,760,000
Industrial 86 -----	do	2,500	150	390	1,900	1,760,000
Industrial 72 -----	do	2,000	135	390	1,550	1,760,000
Industrial 65 -----	do	1,750	120	390	1,350	1,760,000
Industrial 58 -----	do	1,500	105	390	1,250	1,760,000
Industrial 50 -----	do	1,200	105	390	900	1,760,000
Select ¹⁰ -----	Decking -----	1,750	120	390	1,350	1,760,000
Select No. 1 ¹⁰ -----	Decking -----	1,200	105	390	900	1,760,000
No. 2 ¹⁰ -----	Decking -----	1,200	105	390	900	1,760,000

See notes below table.

Table 14-24. Allowable Unit Stresses—Stress-Grade Lumber—Continued

1 Species and commercial grade ¹		2 Rules under which grade	Allowable unit stresses in pounds per square inch				7 Modulus of elasticity "E"
			3 Extreme fiber in bending "f" and tension parallel to grain "t"	4 Horizontal shear "H"	5 Compression perpendicular to grain "c"	6 Compression parallel to grain "c"	
PINE, NORWAY							
Prime Structural	J.&P. ¹⁴	Northern Hardwood & Pine Mfrs. Association.	1,200	75	360	900	1,320,000
Common Structural	J.&P. ¹⁴		1,100	75	360	775	1,320,000
Utility Structural	J.&P. ¹⁴		950	75	360	650	1,320,000
PINE (IDAHO WHITE, LODGE-POLE, PONDEROSA and SUGAR)							
Select Decking ¹⁹	Decking	Western Pine Association.	900	-----	305	-----	1,100,000
Commercial Decking ¹⁹	Decking		700	-----	305	-----	1,100,000
REDWOOD							
Dense Structural ²	J.&P. ⁴ B.&S. ⁴	Redwood Inspection Service.	1,700	110	320	1,450	1,320,000
Heart Structural	J.&P. ⁴ B.&S. ⁴		1,300	95	320	1,100	1,320,000
Dense Structural ²	P.&T		-----	-----	320	1,450	1,320,000
Heart Structural	P.&T		-----	-----	320	1,100	1,320,000
SPRUCE, EASTERN							
1450 f Structural Grade	J.&P. ⁴	Northeastern Lumber Manufacturers Association, Inc.	1,450	110	300	1,050	1,320,000
1300 f Structural Grade	J.&P. ⁴		1,300	95	300	975	1,320,000
1200 f Structural Grade	J.&P. ⁴		1,200	95	300	900	1,320,000
SPRUCE, ENGELMANN							
Select Decking ¹⁹	Decking	Western Pine Association.	750	-----	215	-----	1,100,000
Commercial Decking ¹⁹	Decking		600	-----	215	-----	1,100,000
SPRUCE, SITKA							
Select Dex ¹⁰	Decking	West Coast Lumber Inspection Bureau.	1,100	-----	305	-----	1,320,000
Commercial Dex ¹⁰	Decking		850	-----	305	-----	1,320,000

¹ Abbreviations: J&P=Joists and Planks; B&S=Beams and Stringers; P&T=Posts and Timbers; LF=Light Farming; KD=See note 17; SH=Stress Rated.

² These grades meet the requirements for density.

³ In tension members the slope of grain limitations applicable to the middle portion of the length of the joist and plank and beam and stringer grades used shall apply throughout the length of the piece. This note does not apply to Southern Pine as indicated in note 15.

⁴ The allowable unit stresses for tension parallel to grain "t" and for compression parallel to grain "c" given for these Joist and Plank and Beam and Stringer grades are applicable when the following additional provisions are applied to the grades:

The sum of the sizes of all knots in any 6 inches of the length of the piece shall not exceed twice the maximum permissible size of knot. Two knots of maximum permissible size shall not be within the same 6 inches of length of any face.

⁵ Value applies to pieces used as planks.

⁶ Value applies to 2" thick pieces of Select Structural grade used as joists.

⁷ For 2" thick pieces of Construction, Standard, Structural and Standard Structural grades used as joists:

H=120 when length of split is approximately equal to $\frac{1}{2}$ the width of piece

H=100 when length of split is approximately equal to the width of piece

H=70 when length of split is approximately equal to $1\frac{1}{2}$ times width of piece

⁸ For 3" thick pieces of Select Structural, Construction, Standard, and Standard Structural Grades used as joists:

H=120 when length of split is approximately $2\frac{1}{4}$ ",
H=80 when length of split is approximately $4\frac{1}{2}$ ", and
For 4" thick pieces of Select Structural, Construction, Standard, and Standard Structural grades used as joists:

H=120 when length of split is approximately 3"

H=80 when length of split is approximately 6"

⁹ For beams and Stringers and for Posts and Timbers:

H=120 when length of split is equal to $\frac{1}{2}$ the nominal narrow face dimension

H=100 when length of split is equal to the nominal narrow face dimension

H=80 when length of split is equal to $1\frac{1}{2}$ times the nominal narrow face dimension

Note. Values for lengths of split other than those given in Notes 7, 8 and 9 are proportionate.

¹⁰ These grades cover 3-inch and 4-inch nominal thickness, doubled tongued and grooved material of 6-inch nominal width. Stresses recommended are limited to where material is used as planks.

¹¹ For 2" thick pieces of Construction and Standard Grades used as joists:

H=100 when length of split is approximately equal to $\frac{1}{2}$ the width of piece

H=80 when length of split is approximately equal to the width of piece

H=60 when length of split is approximately equal to $1\frac{1}{2}$ times width of piece

¹² For 3" thick pieces of Select Structural, Construction and Standard grades used as joists:

H=100 when length of split is approximately $2\frac{1}{4}$ ".

H= 70 when length of split is approximately 4½", and for 4" thick pieces of Select Structural, Construction and Standard grades used as joists:

H=100 when length of split is approximately 3"

H= 70 when length of split is approximately 6"

¹³ For Beams and Stringers and for Posts and Timbers:

H=100 when length of split is equal to ¾ the nominal narrow face dimension

H= 90 when length of split is equal to the nominal narrow face dimension

H= 70 when length of split is equal to 1½ times the nominal narrow face dimension

Note. Value for lengths of splits other than those given in notes 11, 12, and 13 are proportionate.

¹⁴ These grades applicable to 2" thickness only.

¹⁵ All stress-grades under the 1960 Standard Grading Rules are all-purpose grades and apply to all sizes. Pieces so graded may be cut to shorter lengths without impairment of the stress rating of the shorter pieces.

Grade restrictions provided by the 1960 Standard Grading Rules apply to the entire length of the piece, and each piece is suitable for use

in continuous spans, over double spans or under concentrated loads without regrading for special shear or other special stress requirements.

The following variations apply to lumber in service under wet conditions or where the moisture content is at or above fiber saturation point, as when continuously submerged, (a) the allowable unit stresses in bending, tension parallel to grain and horizontal shear shall be limited in all thicknesses to the stresses indicated for thicknesses of 5" and up; (b) the allowable unit stresses for compression parallel to grain shall be limited to the stresses indicated for thicknesses of 5" and up reduced by 10%; (c) the allowable unit stresses for compression perpendicular to grain shall be reduced one-third; and (d) the values for modulus of elasticity shall be reduced one-eleventh.

¹⁶ These stresses apply for loading either on narrow face or on wide face.

¹⁷ KD=Kiln dried.

¹⁸ Longleaf may be specified by substituting "Longleaf" for "Dense" in the grade name, and when so specified the same allowable stresses shall apply.

¹⁹ The grades apply for tongued and grooved material 2 to 4 inches in nominal thickness and 6 inches or more in nominal width. Stresses recommended are limited to where the lumber is used as planks.

14-27. Standard Dressed Sizes and Design Values

Table 14-25 gives the American standard dressed sizes of dimension lumber, with moments of inertia and section moduli. It is assumed that the greater dimension of cross section (= h) is vertical.

Table 14-25. Dressed Sizes of Lumber

Nominal size	American standard	Area of section sq in.	$I = \frac{bh^3}{12}$	$S = \frac{bh^2}{6}$
		I_{n^2}	I_{n^4}	I_{n^3}
1 x 3	25/32 x 3 5/8	2.83	3.10	1.71
1 x 4	25/32 x 2 5/8	2.05	1.18	0.90
1 x 6	25/32 x 5 5/8	4.39	11.59	4.12
1 x 8	25/32 x 7 1/2	5.86	27.47	7.32
1 x 10	25/32 x 9 1/2	7.42	55.82	11.75
1 x 12	25/32 x 11 1/2	8.98	99.02	17.22
2 x 4	1 5/8 x 3 5/8	5.89	6.45	3.56
2 x 6	1 5/8 x 5 5/8	9.14	24.10	8.57
2 x 8	1 5/8 x 7 1/2	12.19	57.13	15.23
2 x 10	1 5/8 x 9 1/2	15.44	116.10	24.44
2 x 12	1 5/8 x 11 1/2	18.69	205.95	35.82
3 x 8	2 5/8 x 7 1/2	19.69	92.29	24.61
3 x 10	2 5/8 x 9 1/2	24.94	187.55	39.48
3 x 12	2 5/8 x 11 1/2	30.19	332.69	57.86
4 x 12	3 5/8 x 11 1/2	41.69	459.43	79.90
4 x 16	3 5/8 x 15 1/2	56.19	1,124.92	145.15
6 x 12	5 1/2 x 11 1/2	63.25	697.07	121.23
6 x 16	5 1/2 x 15 1/2	85.25	1,706.78	220.23
6 x 18	5 1/2 x 17 1/2	96.25	2,456.38	280.73
8 x 16	7 1/2 x 15 1/2	116.25	2,327.42	300.31
8 x 20	7 1/2 x 19 1/2	146.25	4,634.30	475.31
8 x 24	7 1/2 x 23 1/2	176.25	8,111.17	690.31

14-28. Design of Beams

a. Flexural Stress.

(1) *Beam span.* For simple beams the span is taken as the distance from face to face of supports plus one-half the required length of bearing at each end. For continuous beams the span is taken as the distance between centers

of bearings on supports over which the beam is continuous.

(2) Extreme fiber stress in bending.

$$f = \frac{Mn}{I} = \frac{M}{S}$$

where n = distance from neutral axis to extreme fiber for a rectangular beam "b" wide and "d" deep

$$I = \frac{bd^3}{12}, S = \frac{bd^2}{6}, \text{ and } n = \frac{d}{2}.$$

b. *Horizontal Shear.* For a rectangular beam "b" wide and "d" deep

$$H = \frac{3V}{2bd}$$

where H = unit horizontal shear stress. There are two methods to calculate V, vertical end shear or end reaction.

Method I:

(1) Neglect all loads within a distance equal to the height of the beam from both ends.

(2) Place the heavy concentrated moving load at a distance three times the height of the beam from the support, but not more than ¼ the span length from support.

(3) Then treat all other loads in the usual manner.

Example: Check the unit horizontal shear in a 6 x 12 beam with a clear span of 10 feet, carrying a uniform load of 1000 ppf.

Solution: Neglecting load one depth of beam from each end

$$D.L. + L.L. = 18 + 1000 = 1018 \text{ ppf}$$

$$V = \frac{1018 \times \left(10 - \frac{2 \times 11.5}{12}\right)}{2} = 4110 \text{ lb}$$

$$H = \frac{3V}{2bd} = \frac{3}{2} \times \frac{4110}{64.69} = 95.3 \text{ psf}$$

Example: Check the horizontal shear stress in a 4 x 12 beam of 12 ft span carrying moving concentrated loads of 4000 lb and 500 lb 6 feet apart.

Solution: Place heavy load 3d from one of the support, but not more than $\frac{1}{4}$ span

$$3d = 3 \times 11\frac{1}{2}" = 2' - 10\frac{1}{2}" < \frac{1}{4} (12') = 3'$$

Taking the moment about one support
 $12R = 4000 \times 9.125 \text{ ft} + 500 \times 3.125$
 $\text{ft } R = V = 3172 \text{ lb}$

$$H = \frac{3V}{2bd} = \frac{3 \times 3172}{2 \times 41.69} = 114 \text{ psf}$$

Method 2: For concentrated load

$$V = \frac{10P(\ell - x)\left(\frac{x}{d}\right)^2}{9\ell\left[2 + \left(\frac{x}{d}\right)^2\right]}$$

For uniformly distributed load

$$V = \frac{W}{2}\left[1 - \frac{2d}{\ell}\right]$$

Where: ℓ = span in inches

x = distance in inches from reaction to load

d = depth of beam in inches

W = total uniform load

P = concentrated load in lb

c. Compression Perpendicular to Grain. For bearing of any length at the ends of a beam and for bearings 6 inches or more in length at any other place along the beam, the unit stress in compression perpendicular to the grain for the grade and species applies. However for shorter bearings not closer than 3 inches from the end, the allowable load per square inch may be increased by multiplying the allowable unit stress in compression perpendicular to the grain by the factor

$$\frac{\ell + \frac{3}{8}}{\ell}$$

where ℓ = length of bearing in inches measured along the grain of the wood.

d. Deflection. When deflection is a factor in design, the deflection formulas are used. For beams supported at both ends, with a uniformly distributed load.

$$D = \frac{5 W \ell^3}{384 EI}$$

Where: D = deflection in inches

W = total distributed load

ℓ = span in inches

E = modulus of elasticity

I = moment of inertia

For beams supported at both ends with concentrated load P at center

$$D = \frac{P \ell^3}{48 EI}$$

Deflection is limited to $1/360$ of the span.

e. Lateral Deflection. Beams, joists, and rafters that are narrow in relation to their depth should be supported laterally. Following are approximate rules for providing adequate lateral support.

(1) If the ratio of depth "d" to breadth "b" is 2 to 1 no lateral support is needed.

(2) If the ratio is 3 to 1, the ends should be held in position.

(3) If the ratio is 4 to 1, the piece should be held in line as in a well-bolted chord member in a truss.

(4) If the ratio is 5 to 1, diagonal bridging should be used at intervals not exceeding 8 feet between bridging.

(6) If the ratio is 7 to 1, both edges should be held in line.

(7) If a beam is subject to both flexure and compression parallel to grain, the ratio may be as much as 5 to 1, if one edge is held firmly in line. If the dead load is sufficient to induce tension on the under side of the rafters, the ratio for the beam may be 6 to 1.

14-29. Design of Columns

a. Column Formula.

$$\frac{P}{A} = \frac{0.30 E}{(\ell/d)^2}$$

The value of P can be obtained by multiplying both sides by A . The values so obtained should not exceed those values listed under safe load column of table 14-26. E is 1.75×10^6 .

b. Spaced Columns.

(1) Spaced columns are formed of two or more individual members with their longitudinal axes parallel, separated at the ends and at the middle point of their length by blocking and joined at the ends by timber connectors capable of developing the required shear resistance. The carrying capacity of the column can be increased by the fixity factor, if the condition is met.

Table 14-26. Safe Loads—Dressed-Lumber Columns

Nominal dimension of cross section (inches)	Length (feet)	Safe load (kips)
4 by 4 -----	6	17.5
	8	9.9
	10	6.3
4 by 6 -----	8	15.3
	10	9.8
	12	6.8
6 by 6 -----	8	52.1
	10	33.6
	12	23.3
6 by 8 -----	10	45.8
	12	31.7
	14	23.4
	16	17.9
8 by 8 -----	10	116.0
	12	80.5
	14	59.2
	16	45.3
8 by 10 -----	10	147.0
	12	102.0
	14	75.0
	16	57.4
	18	45.4
10 by 10 -----	10	300.1
	12	206.3
	14	152.1
	16	116.8
	18	92.5
8 by 12 -----	10	178.0
	12	123.5
	14	90.7
	16	69.5
	18	55.0
10 by 20 -----	12	249.7
	14	184.1
	16	141.4
	18	112.0
	20	90.1
12 by 12 -----	12	446.7
	14	327.6
	16	250.3
	18	197.6
	20	159.9

(2) The fixity factor is $2\frac{1}{2}$ for an end condition "a" where the connectors in the end blocks are placed at the ends of the columns or at a distance not exceeding $\ell/20$ from the ends (fig 14-25). The fixity factor is 3 for an end condition "b" where the connectors in the end blocks are placed a distance of $\ell/20$ to $\ell/10$ from the ends of the columns and the blocks extend to the ends of the columns. For end condition "a"

$$\frac{P}{A} = \frac{0.30 E \times 2.5}{(\ell/d)^2}$$

where d = least dimension of an individual member. For end condition "b"

$$\frac{P}{A} = \frac{0.30 E \times 3.0}{(\ell/d)^2}$$

For individual members of spaced columns $\frac{\ell}{d}$ should not exceed 80, or the distance between center of connectors in end blocks and center of the spacer block divided by "d" should not exceed 40.

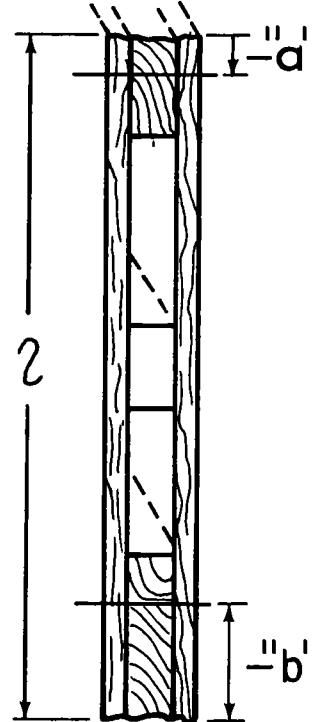


Figure 14-25. Illustration of column end conditions.

c. *Built-Up Columns.* It is sometimes desirable to build up columns from planks or smaller boards spiked or bolted together. Table 14-27 shows the strength of built-up members in percent of solid columns of similar grades. Component planks should not be wider than five times their thickness. Spikes should penetrate two planks and extend well into a third piece and should not be placed farther apart longitudinally than six times the plank thickness. Edges should be tied together with cover plates.

d. *Dimension of Spacer and End Blocks.* The thickness of spacer and end blocks should not be less than the thickness of a side member. Spacer and end blocks one-half the thickness of the side members may be used provided the lengths of the blocks are twice as long as those required for a thickness equal to the side member. The lengths of blocks of thickness between

one-half and full thickness of side members should vary proportionally. Blocks thicker than the side members do not increase the load capacity of the column appreciably.

Table 14-27. *Strength of Built-Up Columns*

/d Ratios	Percentage of solid column strength	/d Ratios	Percentage of solid column strength
6	82	18	65
10	77	22	74
14	71	26	82

e. Combined Bending and Axial Loading. Where members are subjected to combined axial compression and bending, they should be so proportioned that

$$\frac{P/A}{f_c} + \frac{Mn/I}{f_b} \leq 1$$

Where members are subjected to combined tension

$$\frac{P/A}{f_t} + \frac{Mn/I}{f_b} \leq 1$$

f. Round Columns and Tapered Columns.

(1) The allowable load for a round column should not exceed that for a square column of the same cross-sectional area. The least dimension "d" of a round column on this basis is 0.886 times the diameter of the column.

(2) The least dimension "d" of a tapered column is 0.886 times the diameter obtained by adding the minimum diameter to $\frac{1}{3}$ of the difference between the minimum diameter and the maximum diameter, but in no case should it be more than $1\frac{1}{2}$ times the minimum diameter. The unit stress at the small end should not exceed the allowable unit stress for a short column.

14-30. Design of Fastenings

a. Nails and Spikes.

(1) The basic factors that determine the holding power of a nailed joint are the specific gravity of the wood, the diameter of the nail, the depth of penetration, and the moisture content of the wood. When more than one nail or spike is used in a joint, the total allowable load in lateral resistance is the sum of the allowable loads for the individual nails or spikes.

(2) The lateral resistance of nails and spikes driven in side grain of seasoned wood is expressed by the equation

$$P = KD^{3/2}$$

Where: P = safe lateral load

K = constant (see table 14-28)

D = diameter of the nail.

(3) The value P applies where the depth of penetration into the block receiving the point is not less than $\frac{2}{3}$ the length of the nail for softwoods and $\frac{1}{2}$ the length of the nail for hardwoods. When the nail penetrates in the main member a lesser distance, the allowable load shall be determined by straight line interpolation between zero load at zero penetration and full load

Table 14-28. *Values of K for Common Wire Nails*

Species	K
Aspen and largetooth aspen	1,080
Basswood	
Butternut	
Cedar, northern and southern white	
Chestnut	
Cottonwood, black and eastern	
Fir, balsam and white	
Hemlock, eastern	
Pine, lodgepole, ponderosa, sugar, northern white, and western white	
Poplar, yellow	
Spruce, Engelmann, red, Sitka, and white	
Cedar, Alaska, incense, Port Orford, and western red	1,350
Cedar, eastern red	
Cypress, southern	
Douglas fir (Rocky Mountain region)	
Hemlock, west coast	
Pine, Norway	
Redwood	
Tamarack	1,500
Alder, red	
Ash, black	
Birch, paper	
Elm, American and slippery	
Gum, black, red, and tupelo	
Hackberry	
Magnolia, cucumber	
Magnolia, evergreen	
Maple, bigleaf	
Maple (soft), red and silver	
Sugarberry	1,650
Sycamore	
Douglas fir (coast region)	
Larch, western	2,040
Pine, southern	
Ash, commercial white	
Ash, Oregon	
Beech	
Birch, sweet and yellow	
Cherry, black	
Elm, rock	
Hickory, true and pecan	
Locust, honey and black	
Maple (hard), black and sugar	
Oak, commercial red and white	
Walnut, black	

P=Allowable load per nail in pounds.

D=Diameter of nail in inches.

at standard penetration, but the minimum penetration in the main member shall be $\frac{1}{2}$ of the nail length in softwoods and $\frac{2}{5}$ of the nail length in hardwoods.

(4) Safe loads for unseasoned wood are $\frac{3}{4}$ of the values of seasoned wood. For nails driven into end grain, safe loads are $\frac{2}{3}$ of the value for nails driven into side grain. Where nails are used to fasten metal plates to wood, the value of P may be increased 25 percent.

b. Common Wood Screws.

(1) The holding strength of screws is dependent upon the specific gravity of the wood, size of screw, and depth of penetration.

(2) The lateral resistance of screws inserted into side grain of seasoned wood, with a depth of penetration not less than 7 times the diameter of the screw, is

$$P = KD^2$$

Where K = constant (see table 14-29)

D = diameter of shank of screw.

Table 14-29. Values of K for Wood Screws

Species	K
Ash, commercial white	4,800
Ash, Oregon	
Beech	
Birch, sweet and yellow	
Cherry, black	
Elm, rock	
Hickory, true and pecan	
Honey, locust	
Locust, black	
Maple (hard), black and sugar	
Oak, commercial red and white	
Walnut, black	
Douglas fir (coast region)	3,960
Larch, western	
Pine, southern yellow	
Alder, red	3,480
Ash, black	
Birch, paper	
Elm, American and slippery	
Gum, black, red and tupelo	
Hackberry	
Magnolia, cucumber	
Magnolia, evergreen	
Maple, bigleaf	
Maple (soft), red and silver	
Sugarberry	
Sycamore	
Cedar, Alaska, incense, Port Orford and western red	3,240
Cypress, southern	
Douglas fir (Rocky Mountain region)	
Hemlock, west coast	

Table 14-29. Values of K for Wood Screws—Continued

Species	K
Pine, Norway	2,520
Redwood	
Tamarack	
Aspen and largetooth aspen	
Basswood	
Butternut	
Cedar, northern and southern white	
Chestnut	
Cottonwood, black and eastern	
Fir, balsam and commercial white	
Hemlock, eastern	
Pine, lodgepole, ponderosa, sugar, northern white and western white	
Poplar, yellow	2,520
Spruce, Engelmann, red, Sitka and white	

P=Allowable load per screw in pounds.
D=Shank diameter of screw in inches.

(3) If the penetration is less than seven times, but not less than four times the shank diameter, the allowable load should be reduced in proportion to the length of penetration.

(4) For screws inserted into end grain, safe loads are $\frac{2}{3}$ of the value for screws inserted into side grain. Where screws are used to fasten metal plates to wood, the value P may be increased by 25 percent.

c. Lag Screws.

(1) Penetration in side grain of main member (the piece receiving the point of the screw). The basic formula for lateral load is

$$P = KD^2$$

Where K = constant (see table 14-30).

Where the lag screw is inserted into the end grain of the main member, $\frac{2}{3}$ of the calculated load should be used.

(2) The values of K in table 14-30 are based on the penetration of the threaded portion of the screws as follows:

Group 1 woods—11 times the shank diameter of the screw

Group 2 woods— $9\frac{3}{4}$ times

Group 3 woods— $8\frac{1}{2}$ times

Group 4 woods—7 times

If these penetrations cannot be made, the allowable loads must be reduced proportionally with the actual penetration, but the penetration should not be less than five times the diameter of the screw.

(3) Loading perpendicular to grain causes

Table 14-30. Values of K for Lag Screws

Group	Species of wood	K
1	Cedar, northern and southern white	1800
	Fir, balsam and commercial white	
	Hemlock, eastern	
	Pine, ponderosa, sugar, northern white and western white	
	Spruce, Engelmann, red, Sitka and white	
2	Aspen and largetooth aspen	2040
	Basswood	
	Cedar, Alaska, Port Orford and western red	
	Chestnut	
	Cottonwood, black and eastern	
	Cypress, southern	
	Douglas fir (Rocky Mountain type)	
	Hemlock, west coast	
	Pine, Norway	
	Redwood	
3	Tamarack	2280
	Yellow poplar	
	Ash, black	
	Birch, paper	
	Douglas fir (coast region)	
	Elm (soft), American and (gray) slippery	
	Gum, black, red and tupelo	
	Larch, western	
4	Maple (soft) red and silver	2640
	Pine, southern	
	Sycamore	
	Ash, commercial white	
	Beech	
	Birch, sweet and yellow	
	Elm, rock	
	Hickory, true and pecan	
	Maple (hard), black and sugar	
	Oak, commercial red and white	
	Pecan	

P=Allowable load per lag screw in pounds.
D=Shank diameter of lag screw in inches.

the values of K to be modified by the factors shown on table 14-31.

(4) Allowable loads for loading at an angle to grain between 0° and 90° must be determined by the Hankinson formula (fig 14-26).

(5) Where metal plates are used, table 14-30 (the values of K) may be increased 25% for loading parallel to grain of main member, but

no increase is allowed for loading perpendicular to grain of member.

d. Bolts.

(1) *Allowable load.* The allowable load on a bolted joint is dependent upon the bearing value of the wood and the ratio of the length of the bolt in the main member (ℓ) to the diameter of the bolt (D).

(2) *Condition of lumber.* Values given in table 14-32 are for seasoned timbers used in dry locations. For timbers which are occasionally wet but quickly dried, use $\frac{3}{4}$ of values; if wet most of the time, use $\frac{2}{3}$. When green timbers are used in dry locations, use $\frac{2}{5}$ of the values given.

(3) *Combination of members.* Values given in table 14-32 apply when thickness of the side members is equal to or greater than one-half the thickness of the main member (A, fig 14-27). When side members are thinner than one-half the thickness of the main member, a value is selected by using an " ℓ " equal to twice the thickness of the thinner member (B, fig 14-27). When a joint consists of two members (single shear) of equal thickness, use $\frac{1}{2}$ the value obtained by using an " ℓ " equal to twice the thickness of one of the members. When a joint consists of two members of unequal thickness (single shear) use one-half the value obtained by using an " ℓ " equal to twice the thickness of the thinner member (C, fig 14-27).

(4) *For multiple-member joints.* The allowable load is equal to the summation of the loads for the individual shear planes involved; the allowable load for each shear plane should be equal to one-half the tabulated load for a piece having the thickness which is involved (D, fig 14-27).

(5) *Metal side plates.* When metal side plates are used, the parallel to grain values may be increased 25 percent but perpendicular to grain values are not increased.

(6) *Load perpendicular to grain.* When the load acts perpendicular to grain of the main member and is applied through wood or steel side plates, use an " ℓ " equal to the thickness of the main member in obtaining the value Q from table 14-32.

Grain

Table 14-31. Factors for Computing Allowable Lateral Loads for Perpendicular-To-Grain Loading of Lag Screws in Side Grain

Lag screw diameter	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
Factor	1.00	.97	.85	.76	.71	.65	.60	.55	.52	.50

For loads at angle to grain between 0° and 90°, apply the Hankinson formula.

The compressive strength of wood depends on the direction of the grain with respect to the direction of the applied load. It is highest parallel to the grain and lowest perpendicular to the grain, with a variation in these values for different grades within a species and with different species. The variation in strength at angles between parallel and perpendicular is determined by the Hankinson formula. The Scholten nomographs shown here are a graphical solution of this formula which is --

$$N = \frac{PQ}{P \sin^2 \theta + Q \cos^2 \theta}$$

P = Unit stress in compression parallel to the grain.

Q = Unit stress in compression perpendicular to the grain.

θ = Angle between the direction of grain and direction of load normal to the face considered.

N = Unit compressive stress at inclination θ with the direction of grain.

The difference between the two charts is a difference in scale, the one on the right being adapted to the large values of big bolts and the one on the following page for timber joints and lag screw values.

Example A.--Timber joint.

Given: Allowable unit

stresses of

P = 1550 #/sq"

Q = 455 #/sq"

$\theta = 40^\circ$

Required: The value of N.

Connect point X on line AC at value of 455 #/sq"

with point Y on line AB at value of 1550 #/sq"

The radial line of $\theta = 40^\circ$

intersects the isopleth line

at value of 777 #/sq"

which is the value of N.

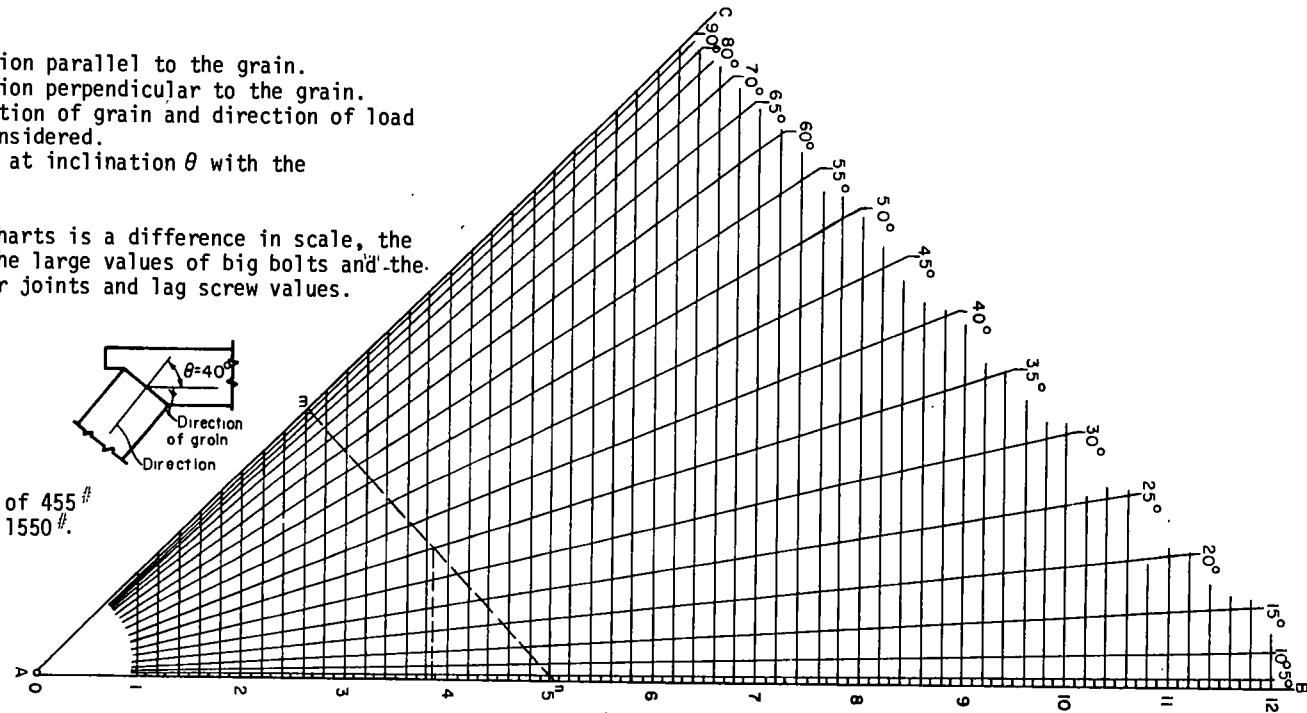
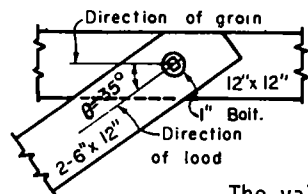


Figure 14-26. Graphical solution of Hankinson formula.

Example B--Bolted joint



The value of the bolt is found by plotting the isopleth line mn, as instructed in example A, using values of $P=5030\#$ and $Q=2620\#$. Bolt values for P and Q are obtained from Table 2. The intersection of line mn with radial line of $\theta=35^\circ$ gives a value of 3870# which is the bolt value at N. bearing.

Values for connectors and lag screws at various angles are determined the same as for bolts. See table 2, for values of P and Q.

Example C.--Timber joints in general.

The direction of load is the direction of the force acting against and normal to the face under consideration. The stress value on two contact faces is governed by the face cut at the lesser angle to the grain. If a joint angle is bisected, as angle A, the stress values of adjacent faces are equal.

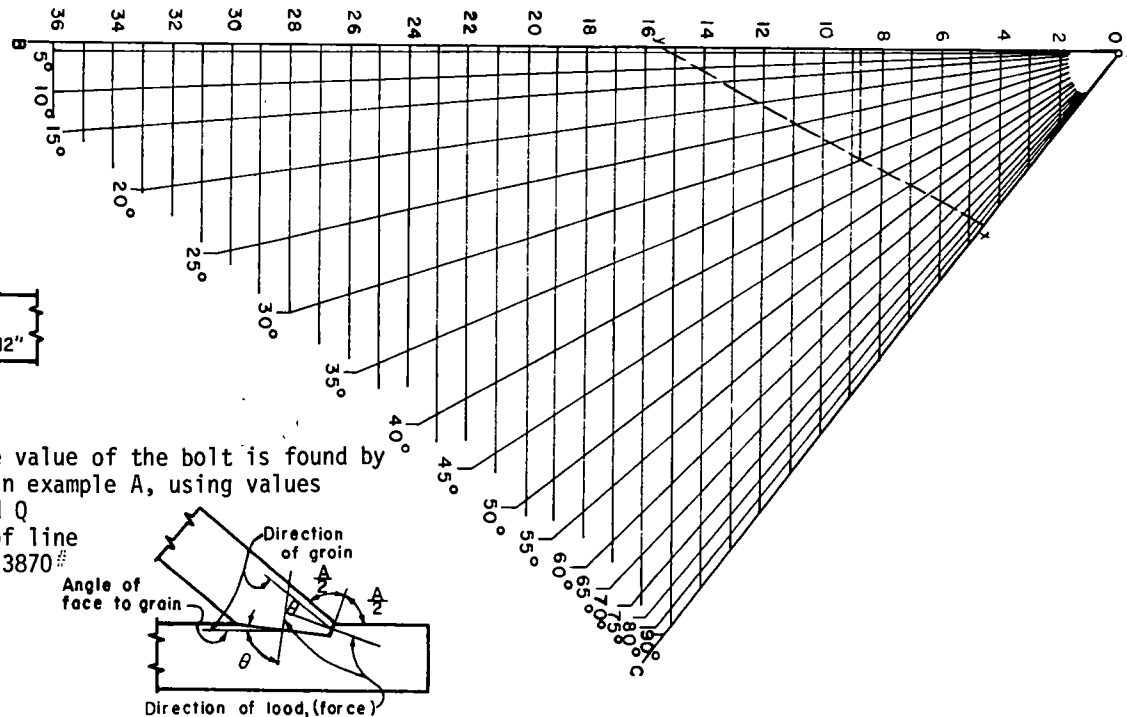
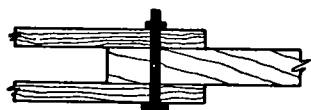


Figure 14-26--Continued.

Table 14-32. Allowable Load in Pounds on One Bolt Loaded at Both Ends (Double Shear)** (Normal Loading Conditions)



				Cypress, tide-water red; Douglas fir (coast and inland); larch, western; pine, southern; redwood; tamarack		Cedar, western red; cedar, Alaska, Port Orford; Douglas fir, (Rocky Mountain); hemlock, west coast; pine, Norway		Cedar, northern and southern white; fir, balsam, commercial white; hemlock, eastern; pine, northern white, Idaho white; ponderosa; spruce, red, Sitka, white, Engelmann		Ash commercial white; beech; birch, sweet and yellow; elm, rock; hickory, true and pecan; maple, hard; oak, commercial red and white		Maple, soft; elm, soft; gum, black, red, tupelo; sycamore		Ash, black, brown; aspen and large toothed aspen; basswood; birch, paper; chestnut; cottonwood, eastern and western; yellow poplar	
Length of bolt in main member <i>l</i>	Diameter of bolt <i>d</i>	<i>l/d</i>	Projected area of bolt <i>A=l×d</i>	Parallel to grain <i>P</i>	Perpendicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpendicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpendicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpendicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpendicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpendicular to grain <i>Q</i>
<i>Inches</i>	<i>Inches</i>		<i>Sq. in</i>												
1 1/2 -----	1/2	3.3	0.8125	1,000	460	780	320	620	240	1,140	660	940	410	720	290
	5/8	2.6	1.0156	1,260	500	970	370	780	280	1,460	740	1,180	470	900	320
	3/4	2.2	1.2188	1,520	560	1,180	410	940	310	1,750	830	1,400	520	1,080	360
	7/8	1.9	1.4129	1,780	620	1,370	460	1,090	340	2,050	910	1,630	560	1,260	400
	1	1.6	1.625	2,030	680	1,560	490	1,250	370	2,340	1,000	1,870	620	1,440	430
2 -----	1/2	4.0	1.00	1,150	550	940	410	770	300	1,330	800	1,130	500	890	350
	5/8	3.2	1.25	1,540	620	1,200	460	960	340	1,780	910	1,440	580	1,100	400
	3/4	2.7	1.50	1,860	700	1,440	490	1,150	380	2,150	1,020	1,730	640	1,330	440
	7/8	2.3	1.75	2,180	770	1,680	560	1,340	420	2,520	1,120	2,020	700	1,560	490
	1	2.0	2.00	2,500	840	1,920	610	1,540	460	2,880	1,220	2,300	770	1,780	530
2 5/8 -----	1/2	5.3	1.3125	1,250	720	1,070	530	940	400	1,440	1,060	1,270	660	1,080	470
	5/8	4.2	1.6406	1,850	830	1,510	600	1,250	440	2,140	1,200	1,820	740	1,440	530
	3/4	3.5	1.9688	2,380	910	1,870	670	1,510	500	2,740	1,330	2,260	830	1,750	590
	7/8	3.0	2.2969	2,830	1,010	2,210	730	1,760	550	3,280	1,460	2,640	910	2,040	650
	1	2.6	2.625	3,260	1,100	2,520	800	2,020	600	3,770	1,600	3,020	1,000	2,330	700
3 -----	1/2	6.0	1.50	1,260	830	1,090	600	980	460	1,450	1,160	1,310	760	1,140	630
	5/8	4.8	1.875	1,940	940	1,630	680	1,390	520	2,230	1,370	1,960	850	1,610	600
	3/4	4.0	2.25	2,590	1,070	2,100	700	1,720	580	3,000	1,520	2,520	950	1,990	670
	7/8	3.4	2.625	3,190	1,150	2,510	840	2,020	620	3,670	1,680	3,010	1,040	2,330	730
	1	3.0	3.00	3,710	1,260	2,880	910	2,300	680	4,270	1,820	3,460	1,140	2,660	800
3 5/8 -----	1/2	7.3	1.8125	1,260	960	1,090	720	980	550	1,450	1,220	1,310	860	1,140	640
	5/8	5.8	2.2656	1,970	1,140	1,700	830	1,540	620	2,270	1,610	2,040	1,030	1,780	720
	3/4	4.8	2.7188	2,810	1,260	2,360	940	2,020	700	3,240	1,840	2,830	1,150	2,330	800
	7/8	4.1	3.1719	3,620	1,390	2,950	1,010	2,420	760	4,180	2,030	3,540	1,270	2,800	890
	1	3.6	3.625	4,430	1,520	3,440	1,100	2,780	830	5,020	2,210	4,140	1,380	3,220	960
4 -----	1/2	8.0	2.00	1,260	970	1,090	770	980	600	1,450	1,210	1,310	890	1,140	710
	5/8	6.4	2.50	1,970	1,250	1,700	910	1,540	680	2,270	1,700	2,050	1,140	1,790	790
	3/4	5.3	3.00	2,830	1,390	2,440	1,020	2,150	770	3,260	2,020	2,920	1,270	2,480	890
	7/8	4.6	3.50	3,730	1,540	3,120	1,120	2,620	840	4,310	2,230	3,740	1,390	3,020	980
	1	4.0	4.00	4,620	1,680	3,740	1,220	3,060	910	5,330	2,440	4,490	1,520	3,530	1,070
	1/2	9.0	2.25	1,260	960	1,090	780	980	650	1,450	1,180	1,310	880	1,140	760
	5/8	7.2	2.8125	1,970	1,360	1,700	1,030	1,540	770	2,270	1,730	2,050	1,240	1,790	900

4½ -----	¾	6.0	3.375	2,830	1,570	2,460	1,140	2,220	850	3,260	2,210	2,940	1,430	2,570	1,000
	⅞	5.1	3.9375	3,850	1,730	3,290	1,260	2,870	950	4,450	2,520	3,950	1,570	3,310	1,100
	1	4.5	4.50	4,870	1,880	4,060	1,370	3,380	1,030	5,630	2,750	4,860	1,720	3,910	1,200
	1½	4.0	5.0625	5,840	2,050	4,730	1,490	3,860	1,120	6,740	2,990	5,680	1,870	4,480	1,310
5 -----	½	10.0	2.50	1,260	940	1,090	770	980	650	1,450	1,120	1,310	850	1,140	760
	⅝	8.0	3.125	1,970	1,380	1,700	1,090	1,540	850	2,270	1,700	2,050	1,260	1,790	1,000
	¾	6.7	3.75	2,830	1,730	2,460	1,270	2,220	950	3,260	2,280	2,940	1,560	2,570	1,100
	⅞	5.7	4.375	3,850	1,920	3,350	1,390	3,010	1,040	4,450	2,740	4,010	1,750	3,470	1,220
	1	5.0	5.00	4,990	2,100	4,240	1,520	3,660	1,140	5,760	3,050	5,090	1,910	4,240	1,330
	1½	4.4	5.625	6,180	2,280	5,110	1,660	4,250	1,250	7,130	3,320	6,130	2,080	4,920	1,450
5½ -----	⅝	8.8	3.4375	1,970	1,360	1,700	1,120	1,540	900	2,270	1,670	2,050	1,240	1,790	1,060
	¾	7.3	4.125	2,830	1,810	2,460	1,390	2,220	1,040	3,260	2,340	2,940	1,660	2,570	1,220
	⅞	6.3	4.8125	3,850	2,110	3,350	1,540	3,010	1,150	4,450	2,890	4,010	1,920	3,480	1,340
	1	5.5	5.50	5,020	2,300	4,340	1,680	3,860	1,260	5,780	3,320	5,210	2,100	4,460	1,460
	1½	4.9	6.1875	6,290	2,510	5,320	1,820	4,560	1,370	7,250	3,650	6,370	2,280	5,280	1,600
6 -----	⅝	9.6	3.75	1,970	1,330	1,700	1,100	1,540	910	2,270	1,620	2,050	1,210	1,790	1,070
	¾	8.0	4.50	2,830	1,850	2,460	1,460	2,220	1,140	3,260	2,290	2,940	1,680	2,570	1,330
	⅞	6.9	5.25	3,850	2,260	3,350	1,680	3,010	1,260	4,450	2,950	4,010	2,050	3,480	1,460
	1	6.0	6.00	5,030	2,520	4,370	1,820	3,950	1,370	5,810	3,520	5,240	2,280	4,560	1,600
	1½	5.3	6.75	6,400	2,740	5,470	1,990	4,840	1,490	7,340	3,980	6,580	2,500	5,590	1,740
6½ -----	⅝	10.4	4.0625	1,970	1,300	1,700	1,070	1,540	900	2,270	1,540	2,050	1,180	1,790	1,040
	¾	8.7	4.875	2,830	1,820	2,460	1,480	2,220	1,200	3,260	2,220	2,940	1,660	2,570	1,390
	⅞	7.4	5.6875	3,850	2,360	3,350	1,800	3,101	1,370	4,450	2,980	4,010	2,150	3,480	1,580
	1	6.5	6.50	5,030	2,700	4,370	1,980	3,950	1,490	5,810	3,650	5,240	2,460	4,560	1,730
	1½	5.8	7.3125	6,400	2,960	5,500	2,160	4,940	1,620	7,340	4,210	6,600	2,700	5,710	1,880
7 -----	⅝	11.2	4.375	1,970	1,270	1,700	1,060	1,540	890	2,270	1,510	2,050	1,150	1,790	1,030
	¾	9.3	5.25	2,830	1,800	2,460	1,480	2,220	1,220	3,260	2,200	2,940	1,630	2,570	1,430
	⅞	8.0	6.125	3,850	2,360	3,350	1,880	3,010	1,460	4,450	2,940	4,010	2,150	3,480	1,720
	1	7.0	7.00	5,030	2,870	4,370	2,140	3,950	1,600	5,810	3,700	5,240	2,600	4,560	1,870
	1½	6.2	7.875	6,400	3,190	5,560	2,330	5,000	1,740	7,340	4,430	6,660	2,900	5,760	2,040
7½ -----	⅝	12.0	4.6875	1,970	1,220	1,700	1,040	1,540	880	2,270	1,460	2,050	1,120	1,790	780
	¾	10.0	5.625	2,830	1,760	2,460	1,440	2,220	1,210	3,260	2,110	2,940	1,610	2,570	1,420
	⅞	8.6	6.5625	3,850	2,340	3,350	1,910	3,010	1,540	4,450	2,900	4,010	2,120	3,480	1,790
	1	7.5	7.50	5,030	2,920	4,370	2,270	3,950	1,720	5,810	3,710	5,240	2,650	4,560	2,000
	1½	6.7	8.4375	6,400	3,400	5,560	2,500	5,000	1,870	7,340	4,500	6,660	3,080	5,760	2,180
8 -----	⅝	12.8	5.00	1,970	1,180	1,700	1,030	1,540	860	2,270	1,390	2,050	1,070	1,790	1,010
	¾	10.7	6.00	2,830	1,730	2,460	1,430	2,220	1,200	3,260	2,040	2,940	1,560	2,570	1,400
	⅞	9.1	7.00	3,850	2,330	3,350	1,900	3,010	1,570	4,450	2,860	4,010	2,120	3,840	1,840
	1	8.0	8.00	5,030	2,950	4,370	2,340	3,950	1,820	5,810	3,650	5,240	2,690	4,560	2,140
	1½	7.1	9.00	6,400	3,530	5,560	2,650	5,000	1,990	7,340	4,540	6,660	3,220	5,760	2,330
	1¾	6.4	10.00	7,860	3,920	6,840	2,860	6,170	2,140	9,070	5,330	8,200	3,580	7,130	2,500

See note below table.

Table 13-32. Allowable Load in Pounds on One Bolt Loaded at Both Ends (Double Shear)* (Normal Loading Conditions)

—Continued

				Cypress, tide-water red; Douglas fir (coast and inland); larch, western; pine, southern; redwood; tamarack		Cedar, western red; cedar, Alaska, Port Orford; Douglas fir, (Rocky Mountain); hemlock, west coast; pine, Norway		Cedar, northern and southern white; fir, balsam, commercial white; hemlock, eastern; pine, northern white, Idaho white; ponderosa; spruce, red, Sitka, white, Engelmann		Ash, commrcial white; beech; birch, sweet and yellow; elm, rock; hickory, true and pecan; maple, hard; oak, commercial red and white		Maple, soft; elm, soft; gum, black, red, tupelo; sycamore		Ash, black, brown; aspen and larget oothed aspen; basswood; birch, paper; chestnut; cottonwood, eastern and western; yellow poplar	
Length of bolt in main member <i>l</i>	Diam-eter of bolt <i>d</i>	<i>l/d</i>	Project-ed area of bolt <i>A=l×d</i>	Parallel to grain <i>P</i>	Perpen-dicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpen-dicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpen-dicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpen-dicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpen-dicular to grain <i>Q</i>	Parallel to grain <i>P</i>	Perpen-dicular to grain <i>Q</i>
<i>Inches</i>	<i>Inches</i>		<i>Sq. in</i>												
9½ -----	¾	12.7	7.125	2,830	1,570	2,460	1,370	2,220	1,150	3,260	1,880	2,940	1,430	2,570	1,340
	⅞	10.9	8.3125	3,850	2,200	3,350	1,810	3,010	1,520	4,450	2,590	4,010	1,990	3,480	1,790
	1	9.5	9.50	5,030	2,860	4,370	2,350	3,950	1,940	5,810	3,470	5,240	2,590	4,560	2,280
	1½	8.4	10.6875	6,400	3,640	5,560	2,930	5,000	2,330	7,340	4,460	6,660	3,300	5,760	2,710
	1¼	7.6	11.875	7,860	4,310	6,840	3,340	6,170	2,540	9,070	5,410	8,200	3,920	7,130	2,960
10 -----	¾	11.4	8.75	3,850	2,160	3,350	1,800	3,010	1,520	4,450	2,570	4,010	1,970	3,480	1,780
	1	10.0	10.00	5,030	2,810	4,370	2,330	3,950	1,940	5,810	3,360	5,240	2,540	4,560	2,270
	1½	8.9	11.25	6,400	3,560	5,560	2,920	5,000	2,360	7,340	4,380	6,660	3,240	5,760	2,760
	1¼	8.0	12.50	7,860	4,330	6,840	3,420	6,170	2,680	9,070	5,340	8,200	3,940	7,130	3,120
11½ -----	1	11.5	11.50	5,030	2,690	4,370	2,230	3,950	1,910	5,810	3,200	5,240	2,450	4,560	2,220
	1½	10.2	12.9375	6,400	3,460	5,560	2,830	5,000	2,380	7,340	4,100	6,660	3,140	5,760	2,770
	1¼	9.2	14.375	7,860	4,220	6,840	3,460	6,170	2,840	9,070	5,170	8,200	3,840	7,130	3,320
12 -----	1	12.0	12.00	5,030	2,620	4,370	2,220	3,950	1,880	5,810	3,110	5,240	2,880	4,560	2,200
	1½	10.7	13.50	6,400	3,380	5,560	2,780	5,000	2,350	7,340	4,020	6,660	3,070	5,760	2,750
	1¼	9.6	15.00	7,860	4,150	6,840	3,420	6,170	2,980	9,070	5,040	8,200	3,780	7,130	3,340

*—Three (3) member joint. Common bolts. Yield point 45,000 lbs. per sq. in. For high strength bolts, higher loads may be used.

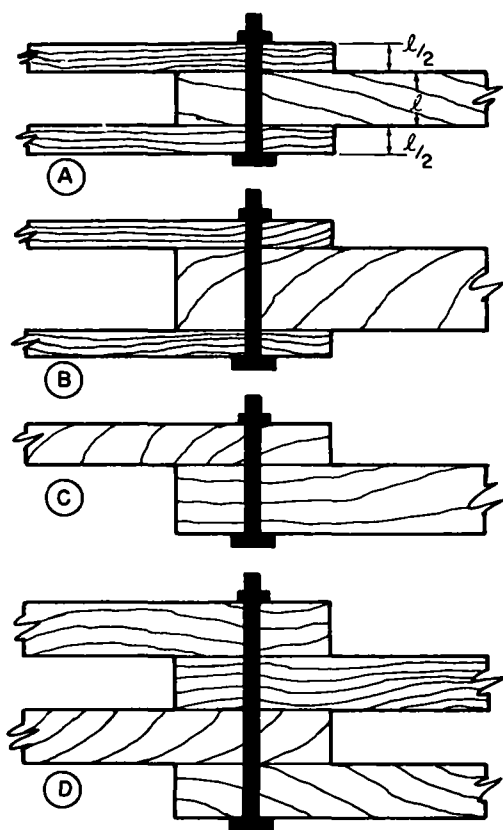


Figure 14-27. Bolted wood joints.

(7) *Load at an angle to grain.* When the load acts at an angle between 0° and 90° (fig 14-26) with the grain of the main member, use a value of ℓ equal to the thickness of the main member for determining P and Q from table 14-32. The allowable bolt value is determined by Hankinson formula as follows:

$$N = \frac{PQ}{P \sin^2 \theta + Q \cos^2 \theta}$$

Where: N = allowable value per bolt in a direction at inclination θ with the direction of grain

P = allowable value per bolt in compression parallel to grain

Q = allowable value per bolt in compression perpendicular to grain

θ = angle between the direction of the load and the direction of the grain.

(8) *Placement of Bolts in joints.*

(a) *Spacing of bolts in a row.*

1. Spacing of bolts is the distance between bolts measured from the center of the bolts.

2. For parallel-to-grain loading, the minimum spacing is 4 times the bolt diameter.

3. For perpendicular-to-grain loading, when the design load is equal to the bolt bearing capacity of the side members, the spacing should be at least 4 times the diameter of the bolt. When the design load is less than the bolt bearing capacity of the side members, the spacing may be reduced proportionately.

(b) *Spacing of rows of bolts* (fig 14-28).

1. Row of bolts is defined as a number of bolts in a line parallel to the direction of the load.

2. For parallel to grain loading, the row spacing is usually determined by dividing the width of the member by the number of rows. However, the minimum distance to the edge must be met.

3. For perpendicular-to-grain loading the spacing between rows should be at least—

$2\frac{1}{2}$ times the bolt diameter for ℓ/d of 2

5 times the bolt diameter for ℓ/d of 6 or

more

Interpolate for intermediate values of ℓ/d where

ℓ = length of bolt in a main member

d = diameter of bolt

4. Staggering of bolts in the rows may be desirable to avoid splitting.

(c) *End distance.* End distance is distance from the center of the bolt hole nearest to end to the end of the member. The end distance for members in tension should be at least $7d$ for softwoods and $5d$ for hardwoods. For members in compression it should be at least $4d$ for both soft and hardwoods.

(d) *Edge distance* (fig 14-28). The distance from the edge of the member to the center of the nearest bolt hole must meet the following:

1. For parallel to grain loading, the edge distance should be at least $1\frac{1}{2}d$.

2. For perpendicular to grain loading, the edge distance should be at least $4d$.

(9) *Length of bolts.*

(a) The minimum length of a bolt used in timber construction should be equal to the sum of the thicknesses of the individual members of the bolted joint, plus the thickness of the washers, plus the thickness of the nut. In addition, the usual practice is to allow a minimum excess of about $\frac{1}{2}$ inch.

(b) The thickness of the American standard regular nut is equal to $\frac{7}{8}d$.

e. *Timber Connectors.*

(1) *Types available.* The types of timber

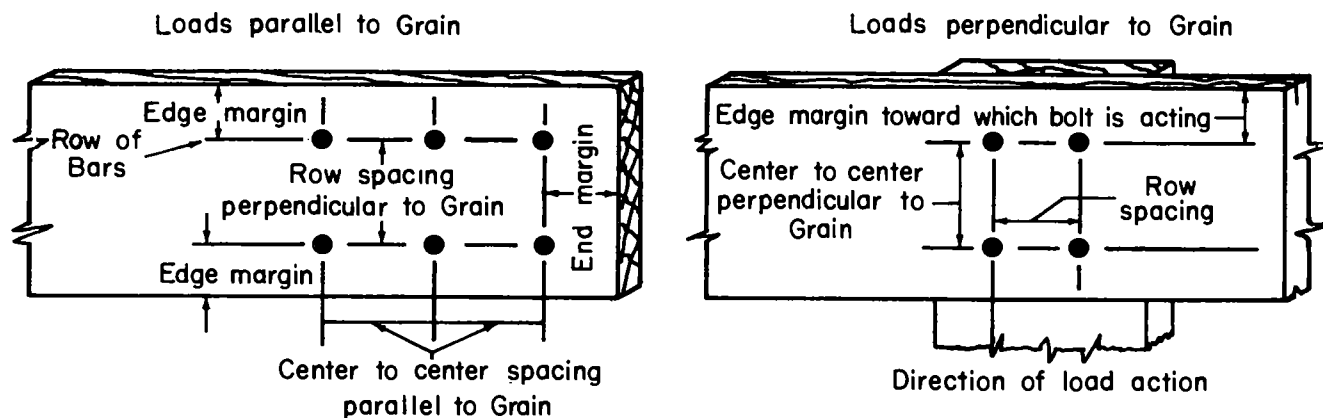


Figure 14-28. Method of spacing bolts in rows.

connectors which are standard items of issue include the 2½- and 4-inch split ring and the 4-inch toothed ring. The design data below cover the split-ring connector, which is the type regularly used. It is installed quickly and accurately in a groove made by a cutter in a ¾-inch electric drill, whereas the toothed ring is embedded by drawing the timbers together with a high-strength bolt with smooth thread and a ball-bearing washer, to be then replaced by the regular bolt. The 4-inch toothed-ring connector has design values about 10 percent below those of the 4-inch split ring. It is used in comparatively light construction or in isolated locations where a heavy-duty drill is not available. Bolt diameters are ½ inch for 2½-inch rings, ¾ inch for 4-inch rings. Plate washer sizes are 2 by 2 by ⅛ inch and 3 by 3 by ⅜ inch for 2½- and 4-inch rings, respectively.

(2) *Species groups.* The connector load groupings for various species of lumber of structural grades are as follows:

Connector load group	Species
A	Dense Douglas fir, oak, and longleaf yellow pine.
B	Coastal Douglas fir, larch, and shortleaf yellow pine.
C	Cypress, western hemlock, Norway pine, and redwood.

(3) *Edge and end distances.* Minimum distances from center of connector to edges and end of members are shown in figures 14-29, 14-30, 14-31, and 14-32.

(4) *Spacing.*

(a) For 2½-inch rings, 3½-inch spacing is minimum and permits applying 75 percent of the full loads given below. For full load and

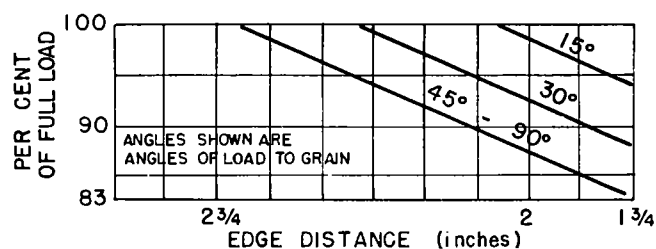


Figure 14-29. Edge distance for 2 1/2-inch split rings.

various angles of load to grain, spacings vary from 4¼ inches perpendicular to grain for loads at 60° to 90° with the grain, to 6¾ inches parallel with the grain for loads parallel with the grain.

(b) For 4-inch rings, the above values are: 5-inch spacing for 75 percent loading varying to 6-inch spacing perpendicular to grain and 9-inch spacing parallel with grain for loads parallel with the grain.

(5) *Allowable loads.* For satisfactory distances and spacing, and for long-term or permanent loading, safe loads per connection are

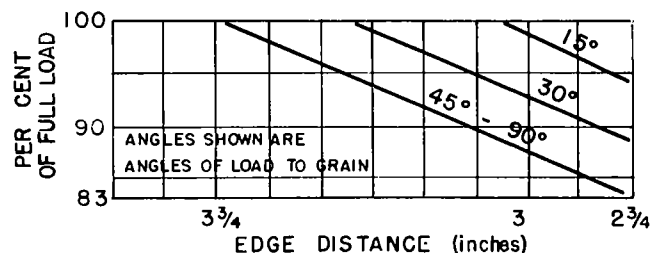


Figure 14-30. Edge distance for 4-inch split rings.

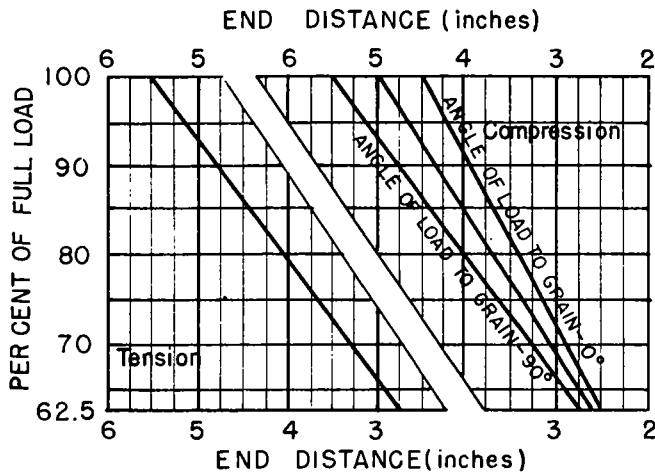


Figure 14-31. End distance for 2 1/2-inch split rings.

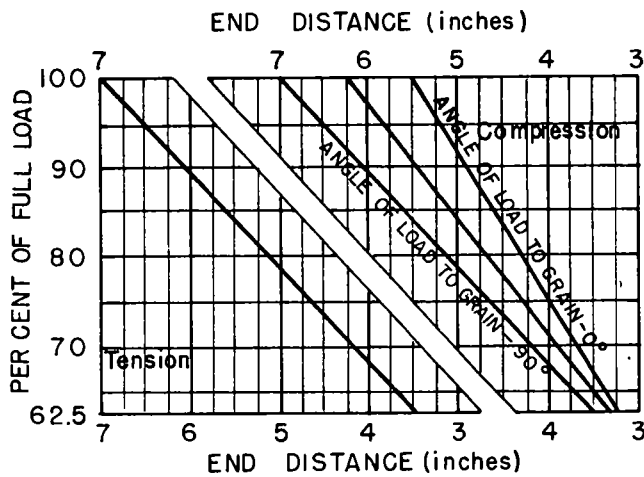


Figure 14-32. End distance for 4-inch split rings.

shown in figures 14-33 and 14-34. The values may be increased 15 percent for loads applied for periods of not over 3 months or for snow loads, 50 percent for 0 wind or earthquake loads, or 100 percent for impact loads.

14-31. Design of Piles

a. *General.* For details on design, construction, and maintenance of pile structures, refer to TM 5-258.

b. *End-Bearing Piles.* The load which can be carried by an end-bearing pile is dependent on either the bearing capacity of the foundation on which the material rests or the strength of the pile acting as a column. For most soils and for some soft rock formations, load estimates are based upon the results of load tests, together with an analysis of boring records. For bedrock or

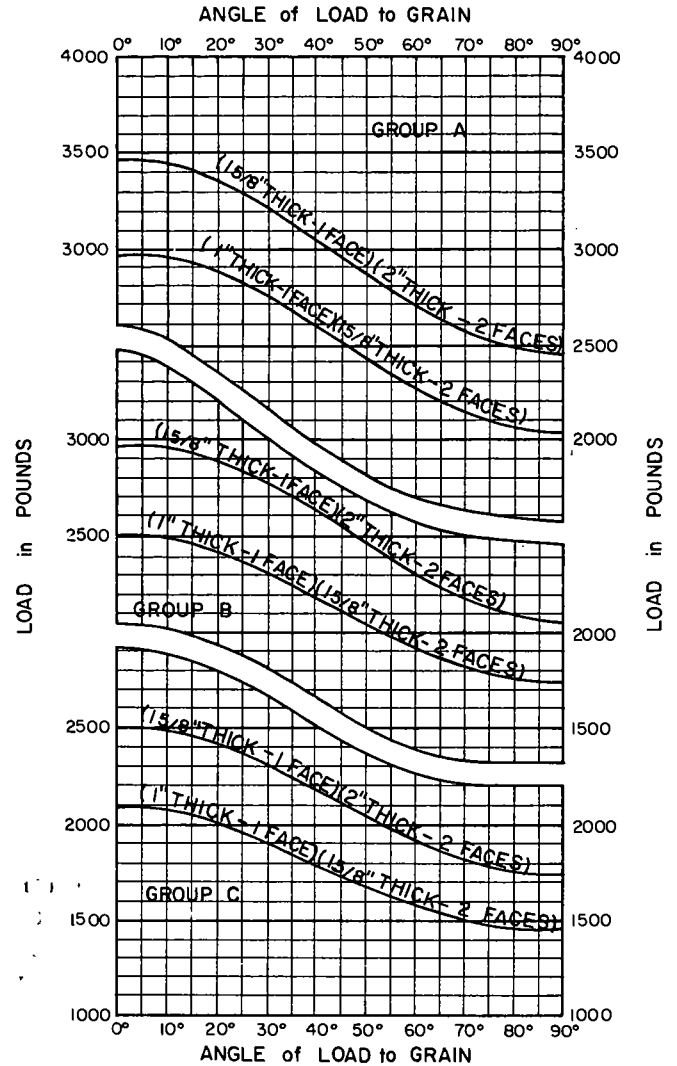


Figure 14-33. Safe loads for one 2 1/2-inch ring and bolt in single shear.

other very hard strata, the column formulas below are used.

(1) *Unsupported length.* An end-bearing pile is more likely to fail because of the tendency of the pile to bend under load and overstress the extreme fibers, rather than to fail by direct compression. The slenderness ratio of a column is a measure of the tendency of the column to bend under its load.

(a) The slenderness ratio of timber piles is the ratio of unsupported length to average pile diameter, L/d . The diameter of a timber pile must be large enough to keep the value of the slenderness ratio within 40.

(b) The slenderness ratio of steel piles is the ratio of the unsupported length to the least

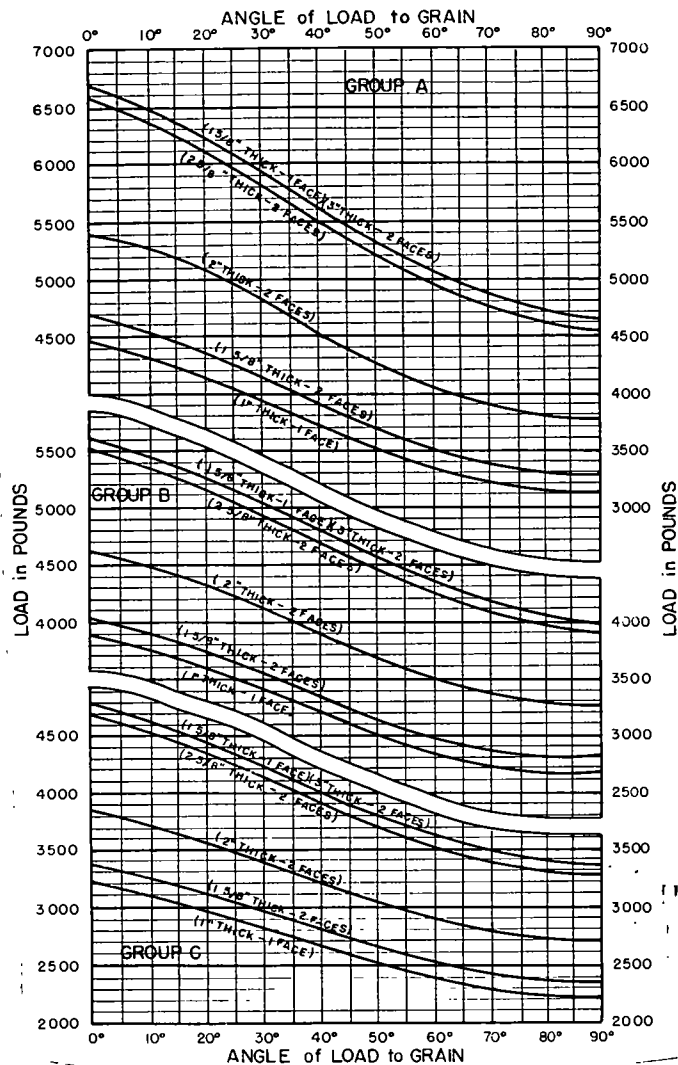


Figure 14-84. Safe loads for one 4-inch ring and bolt in single shear.

radius of gyration, L/r . The value of L/r should not exceed 200.

(c) If d and r are in inches, the unsupported length L is taken as the length in inches from the lowest brace connection to the ground level, plus some part of the penetration. This varies from one-eighth of the penetration for firm soils to one-third for soft soils, except that the entire penetration is used for timber piles which do not penetrate at least 10 feet. For wood piles well fixed in firm soils and not braced at the top, the average diameter may be taken at a point one-third the distance from butt to tip.

(2) Timber end-bearing piles.

For L/d less than 11.

$$P = fA$$

For L/d between 11 and 40

$$P = fA \left(1 - \frac{L}{60d} \right)$$

Where: P = safe load, lb per pile

f = allowable stress in compression psi as given in table 14-24.

A = cross sectional area of pile, sq in.

d = average diameter, in.

L = unsupported length of pile, in.

(3) Steel end-bearing piles.

For L/r less than 140

$$P = A \left[21,300 - \frac{1}{2} \left(\frac{L}{r} \right)^2 \right]$$

For L/r between 140 and 200

$$P = A \left(23,000 - 85 \frac{L}{r} \right)$$

where r = least radius of gyration

c. Friction Piles.

(1) *Use of formulas.* The bearing capacity of a pile whose principal support is from friction may be calculated using the Engineer News Formulas. These formulas should be used with the following considerations:

(a) The theoretical safety factor is 6, but actual factors of safety determined by tests have varied from less than one to as high as 10.

(b) In granular, nonplastic soils, such as gravel and sand, the formulas are reliable.

(c) The formulas are not recommended for use when piles are driven in silt and clay soils. If piles are to be driven in silty or clayey soils, reference should be made to TM 5-258.

(d) In saturated fine sands, the formulas usually indicate the allowable load as being less than that which may develop after driving. Load tests should be conducted.

(2) Engineer news formulas.

(a) Timber piles driven with a drop hammer

$$P = \frac{2 Wh}{S + 1.0}$$

(b) Timber piles driven with a single-acting steam or pneumatic hammer

$$P = \frac{2 WH}{S + 0.1}$$

(c) Timber piles driven with a double-acting steam, pneumatic or diesel hammer

$$P = \frac{2 E}{S + 0.1}$$

Where:

- P = safe load capacity per pile, in lb
 W = weight of drop hammer or ram of steam or pneumatic hammer, in lb
 h = average height of fall of drop hammer for the last 6 blows, in feet
 H = stroke of ram, in feet
 S = average pile penetration, in inches per blows of a drop or last 20 blows of steam or pneumatic hammer
 E = driving energy in ft-lb per blow of a double-acting steam or pneumatic hammer.

(d) Driving energy E can be estimated as follows:

Wt of hammer in lb	Strokes per min	Energy in ft-lb per blow
5000	225	4,150
	195	3,720
	170	3,280
7000	145	8,750
	140	8,100
	135	7,500
	130	6,800

d. *Load Test.* The test load will be twice the proposed design load on the pile, as estimated by a pile-driving formula, the static method, or other means. The test load will be applied in seven increments, equal to one-half, three-fourths, one, one and one-fourth, one and one-half, one and three-fourths, and two times the proposed working load. Readings of settlements and rebounds should be referred to a permanent bench mark and recorded to one-thousandth of a foot for each increment or decrement of load. After the proposed working load has been applied and for each increment thereafter, the test load should remain in place until there is no settlement in a 2 hour period. The total test load should remain in place until settlement does not exceed one-thousandth of a foot in 48 hours. The total load should be removed in increments not exceeding one-fourth of the total test load with intervals of not less than 1 hour. The rebound should be recorded after each increment is removed. The maximum allowable pile load

(safe design load) will be one-half that which caused a net settlement of not more than one-hundredth of an inch per ton of total test load or will be one-half that which causes a gross settlement of 1 inch, whichever is less.

14-32. Plywood

a. *General.* Plywood is a board or panel consisting of an odd number of layers or plies of wood veneer with alternate plies laid crosswise. These plies are bonded together under hydraulic pressure with either water resistant or waterproof adhesives. The outside plies are called faces, and the center ply or plies are called cores. The plies immediately below and at right angles to the face plies are called cross-bands. The strength of plywood in all directions depends on the cross-laminating veneers.

b. *Types and Grades.* Plywoods are divided into two general types, interior and exterior. The interior type is designed to retain its shape and most of its strength only when wet occasionally and subjected to a normal drying process. The exterior type is designed to retain its shape and strength when repeatedly wet and dried or otherwise subjected to outside conditions of exposure. The grades in each type are established by the quality of the veneer on the two face panels. The grades in descending order of quality are designated as A, B, C, and D. Grade A-A has grade A veneer on both faces. Grade A-B has grade A on one face and grade B on the other face. Usually grade C is used for the inner plies of exterior type plywood and grade D is used for the inner plies of interior type plywood.

c. *Strength of Plywood.* When calculating the allowable load using working stresses of plywood, care must be given to the direction of applied stress and the direction of face grain. Table 14-33 and figure 14-35 illustrate approximate methods of calculating strength of plywood in several different applications.

d. *Working Stress for Plywood (Douglas Fir).* Table 14-34 lists the recommended working stresses of Douglas Fir plywood to be used with table 14-33.

Table 14-33. Approximate Methods of Calculating the Strength of Plywood¹

Property	Direction of stress with respect to direction of face grain	Area to be considered	Unit stress to be used
Tension	Parallel or perpendicular.	Parallel plies ² only	Unit stress for extreme fiber in bending.
	$\pm 45^\circ$	Full cross-sectional areas	1/6 unit stress for extreme fiber in bending.
Compression	Parallel or perpendicular.	Parallel plies ² only	Unit stress in compression parallel to grain.
	$\pm 45^\circ$	Full cross-sectional areas	1/3 unit stress in compression parallel to grain.
Bearing at right angles to plane of plywood		Loaded area	Unit stress for extreme fiber in bending.
Load in bending	Parallel or perpendicular.	Bending moment $m = KSI/c$ where $S =$ unit stress for extreme fiber in bending, $I =$ moment of inertia computed on basis of parallel plies only, $c =$ distance from neutral axis to outer fiber or outermost ply having its grain in the direction of the span, $K = 1.50$ for 3-ply plywood having the grain of the outer plies perpendicular to the span, $K = 0.85$ for all other plywood.	Unit stress for extreme fiber in bending.
Deflection in bending.	Parallel or perpendicular.	Deflection may be calculated by the usual formulas, taking as the moment of inertia that of the parallel plies plus 1/20 that of the perpendicular plies. (When face plies are parallel, the calculation may be simplified, with but little error, by taking the moment of inertia as that of the parallel plies only.)	Unit value for modulus of elasticity.
Deformation in tension or compression.	Parallel or perpendicular.	Parallel plies ² only	Unit of value for modulus of elasticity.
Shear through thickness.	Parallel or perpendicular.	Full cross-sectional area	Double unit stress in horizontal shear ³ .
	$\pm 45^\circ$	Full cross-sectional area	4 times unit stress in horizontal shear.
Shear in plane of plies.	Parallel or perpendicular.	Full shear area. Plywood beams, horizontal shear (A, fig. 14-35).	3/4 unit stress in horizontal shear.
		Area of contact between plywood and flange or framing member. I- or box-beams with plywood webs. Shear between plies of web or between web and flange (B, fig. 14-35).	3/8 unit stress in horizontal shear.
		Panels having plywood covers stressed in compression or tension, or both. Shear between plies or between cover and framing members when depth of member exceeds twice its width and end headers are used or when depth is not more than twice the width and no headers are used. Interior framing members (C, fig. 14-35). Framing members at edge of panel (D, fig. 14-35).	3/4 unit stress in horizontal shear. 3/8 units stress in horizontal shear.

See notes below table.

Table 14-33. Approximate Methods of Calculating the Strength of Plywood¹—Continued

Property	Direction of stress with respect to direction of face grain	Area to be considered	Unit stress to be used
	$\pm 45^\circ$	Area of contact between plywood and flange or framing member. I- or box-beams with plywood webs. Shear between plies of web or between web and flange (B, fig. 14-35). Panels having plywood covers stressed in compression, or tension, or both. Shear between plies or between cover and framing members when depth of member exceeds twice its width and end headers are used or when depth is not more than twice the width and no headers are used. Interior framing members (C, fig. 14-35). Framing members at edge of panel (D, fig. 14-35).	1/2 unit stress in horizontal shear. Unit stress in horizontal shear. 1/2 unit stress in horizontal shear.

¹ The suggested simplified methods of calculation apply reasonably well with usual plywood types under ordinary conditions of service. It is recognized, however, that they are not entirely valid for all types of plywood and plywood constructions or for all spans and span-depth ratios. Also the methods given are not applicable to structures so proportioned that the plywood is in the buckling range, in which event the results will be too high.

² By "parallel plies" is meant those plies whose grain direction is parallel to the direction of principal stress.

³ This value should be reduced if gaps occur at edge joints.

Table 14-34. Recommended Working Stresses for Plywood (Douglas Fir)

In Bending, Tension and Compression (except bearing and 45° stresses) consider only those plies with their grain direction // to the principal stress.

DRY LOCATION

Type of stress	Ext-DFPA A-A	EXT-DFPA A-B EXT-DFPA Plyshield (A-C)	Form (B-B) EXT-DFPA Utility (B-C) EXT-DFPA Sheathing (C-C) EXT-DFPA Concrete Plyform (B-B) Plyscord (C-D)	Interior A-A Interior A-B Plypanel (A-D) Plybase (B-D) Note: Apply the following percentages to the stresses for the corresponding Exterior grade. See example at bottom of page.
EXTREME FIBER in bending				
Face grain // to span	2,188	2,000	1,875 ✓	100%
" ⊥ "	1,875	1,875	1,875	80%
TENSION				
// to face grain (3-ply only*)	2,188	2,000	1,875	100%***
⊥ to face grain	1,875	1,875	1,875	80%
$\pm 45^\circ$ to face grain	337	320	310	85%
COMPRESSION				
// to face grain (3-ply only*)	1,605	1,460	1,375	100%***
⊥ to face grain	1,375	1,375	1,375	70%
$\pm 45^\circ$ to face grain	496	472	460	80%
BEARING (on face)	405	405	405	100%
SHEAR, rolling, in plane of plies**				
// or ⊥ to face grain	79	72	68	75%
$\pm 45^\circ$	105	96	90	75%
SHEAR, in plane ⊥ to plies**				
// or ⊥ to face grain	210	192	180	85%
$\pm 45^\circ$	420	384	360	85%
MODULUS OF ELASTICITY in bending				
Face grain // to span	1,600,000	1,600,000	1,600,000	100%
" ⊥ "	1,600,000	1,600,000	1,600,000	70%

* For tension or compression, // to grain, in 5-ply or thicker, use values for 3-ply, but in next lower grade.

** For certain conditions where stress concentrations exist these working stresses for rolling shear should be reduced by 50%.

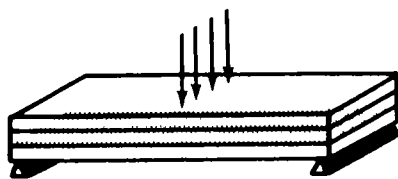
*** For 5. or more plies use 90%.

WET OR DAMP LOCATION

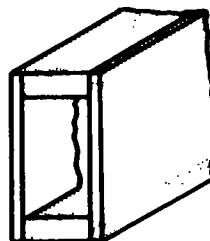
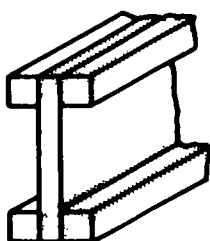
Where moisture content will exceed 16%, decrease by 20% values shown for Dry Location for following properties:

Extreme fiber in bending, tension and compression both // and ⊥ to the grain and at 45° , and bearing. (No change in values for shear or modulus of elasticity.)

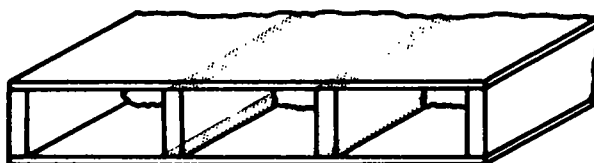
Example: The working stress in compression // for Plypanel 5-ply (1238 psi) is found by multiplying the value for EXT-DFPA Plyshield 5-ply, 1375 psi, by 90%, the reduction factor shown in the last column and footnotes * and ***.



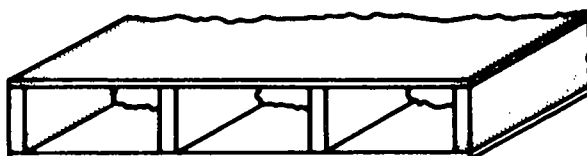
A



B



C



D

Figure 14-35. Illustrations of uses of plywood.

CHAPTER 15

CONSTRUCTION MATERIALS

Section I. WOOD

15-1. Board Measure

a. Lumber quantities are expressed in feet feet board measure (ft bm) or in board feet (bd ft), or in thousand board feet (M bd ft). One board foot (or ft bm) is the amount of lumber in a rough-sawed board 1 foot long, 1 foot wide, and 1 inch thick (144 cubic inches) or the equivalent volume in any other shape. These original or "nominal" dimensions and volumes determine the number of board feet in a given quantity of dressed lumber, regardless of the fact that the process of surfacing or other machining has reduced the actual dimensions and volume. Under American standards, for example, a dressed board designated as 1 inch by 12 inches is in

fact 25/32 inch by 11½ inches. This must be taken into account in computing the amount of lumber needed for a given job. Thus, one hundred 1-inch by 12-inch dressed boards 16 feet long contain—

$$\frac{100 \times 1 \times 12 \times 16}{12} = 1,600 \text{ board feet, but have an actual area of only}$$

$$\frac{100 \times 11\frac{1}{2} \times 16}{12} = 1,533 \text{ square feet; so that if 1,600 square feet of 1-inch by 12-inch material are desired, 1,670 board feet plus allowance for wastage, must be ordered.}$$

b. Table 15-1 gives the number of board feet in one piece of lumber of the sizes given.

Table 15-1. Board Feet

Size of piece (inches)	Length of piece (feet)							
	10	12	14	16	18	20	22	24
2 by 4	6 2/3	8	9 1/3	10 2/3	12	13 1/3	14 2/3	16
2 by 6	10	12	14	16	18	20	22	24
2 by 8	13 1/3	16	18 2/3	21 1/3	24	26 2/3	29 1/3	32
2 by 10	16 2/3	20	23 1/3	26 2/3	30	33 1/3	36 2/3	40
2 by 12	20	24	28	32	36	40	44	48
2 by 14	23 1/3	28	32 2/3	37 1/3	42	46 2/3	51 1/3	56
2 by 16	26 2/3	32	37 1/3	42 2/3	48	53 1/3	58 2/3	64
3 by 6	15	18	21	24	27	30	33	36
3 by 8	20	24	28	32	36	40	44	48
3 by 10	25	30	35	40	45	50	55	60
3 by 12	30	36	42	48	54	60	66	72
3 by 14	35	42	49	56	63	70	77	84
3 by 16	40	48	56	64	72	80	88	96
4 by 4	13 1/3	16	18 2/3	21 1/3	24	26 2/3	29 1/3	32
4 by 6	20	24	28	32	36	40	44	48
4 by 8	26 2/3	32	37 1/3	42 2/3	48	53 1/3	58 1/3	64
4 by 10	33 1/3	40	46 2/3	53 1/3	60	66 2/3	73 1/3	80
4 by 12	40	48	56	64	72	80	88	96
4 by 14	46 2/3	56	65 1/3	74 2/3	84	93 1/3	102 2/3	112
4 by 16	53 1/3	64	74 2/3	85 1/3	96	106 2/3	117 1/3	128
6 by 6	30	36	42	48	54	60	66	72
6 by 8	40	48	56	64	72	80	88	96
6 by 10	50	60	70	80	90	100	110	120
6 by 12	60	72	84	96	108	120	132	144
6 by 14	70	84	98	112	126	140	154	168
6 by 16	80	96	112	128	144	160	176	192
6 by 18	90	108	126	144	162	180	198	216
6 by 20	100	120	140	160	180	200	220	240

Table 15-1. Board Feet—Continued.

Size of piece (inches)	Length of piece (feet)							
	10	12	14	16	18	20	22	24
8 by 8	53 1/3	64	73 2/3	85 1/3	96	106 2/3	117 1/3	128
8 by 10	66 2/3	80	93 1/3	106 2/3	120	133 1/3	146 2/3	160
8 by 12	80	96	112	128	144	160	176	192
8 by 14	93 1/3	112	130 2/3	149 1/3	168	186 2/3	205 1/3	224
10 by 10	83 1/3	100	116 2/3	133 1/3	150	166 2/3	183 1/3	200
10 by 12	100	120	140	160	180	200	220	240
10 by 14	116 2/3	140	163 1/3	186 2/3	210	233 1/3	256 2/3	280
10 by 16	133 1/3	160	186 2/3	213 1/3	240	266 2/3	293 1/3	320
12 by 12	120	144	168	192	216	240	264	288
12 by 14	140	168	196	224	252	280	308	336
12 by 16	160	192	224	256	288	320	352	384
14 by 14	163 1/3	196	228 2/3	261 1/3	294	326 2/3	359 1/3	392
14 by 16	186 2/3	224	261 1/3	298 2/3	336	373 1/3	410 2/3	448

15-2. International Log Rule

A log rule, or scale, is marked at each inch with the number of board feet which can be sawed from logs if measured inside the bark at the small end. Many such rules have been devised, recognized in the lumber industry, and used in various localities. The international 1/4-inch log rule, which is based on 1/4-inch saw kerfs, has been adopted by statute in some states and may eventually become the universal standard. In applying the rule, no interpolation is made for diameters between inch marks, but scaling practice in some localities permits using the next higher inch for diameters with a fraction larger than 1/2 inch; for example, a log 23 3/4 inches in diameter is scaled as 24 inches. The scale is given in table 15-2.

Table 15-2. Log Scale

Diameter (inches)	Length of log in feet (board measure)						
	8	10	12	14	16	18	20
6	10	10	15	15	20	25	25
7	10	15	25	30	30	35	40
8	15	20	25	35	40	45	50
9	20	30	35	45	50	60	70
10	30	35	45	55	65	75	85
11	35	45	55	70	80	95	105
12	45	55	70	85	95	110	125
13	55	70	85	100	115	135	150
14	65	80	100	115	135	155	175
15	75	95	115	135	160	180	205
16	85	110	130	155	180	205	235
17	95	125	150	180	205	235	265
18	110	140	170	200	230	265	300
19	125	155	190	225	260	300	335
20	135	175	210	250	290	330	370
21	155	195	235	280	320	365	410
22	170	215	260	305	355	405	455
23	185	235	285	335	390	445	495
24	205	255	310	370	425	485	545
25	220	280	340	400	460	525	590
26	240	305	370	435	500	570	640
27	260	330	400	470	540	615	690
28	280	355	430	510	585	665	745
29	305	385	465	545	630	715	800
30	325	410	495	585	675	765	860
31	350	440	530	625	720	820	915
32	375	470	570	670	770	875	980
33	400	500	605	715	820	930	1045
34	425	535	645	760	875	990	1110
35	450	565	685	805	925	1050	1175
36	475	600	725	855	980	1115	1245
37	505	635	770	905	1040	1175	1315
38	535	670	810	955	1095	1245	1390
39	565	710	855	1005	1155	1310	1465
40	595	750	900	1060	1220	1380	1540
41	625	785	950	1115	1280	1450	1620
42	655	825	995	1170	1345	1525	1705
43	690	870	1045	1230	1410	1600	1785
44	725	910	1095	1290	1480	1675	1870
45	755	955	1150	1350	1550	1755	1960
46	795	995	1200	1410	1620	1835	2050
47	830	1040	1255	1475	1695	1915	2140
48	865	1090	1310	1540	1770	2000	2235

15-3. Wood Design Data

Data pertaining to design of wood structures, including dressed sizes, allowable stresses, and formulas for design of beams, columns, wood piles and fastenings, will be found in section V, chapter 14.

Section II. STEEL PRODUCTS

15-4. Corrugated Sheet Metal

a. Black and galvanized sheet iron with 2½-inch corrugation is stocked in oversea depots as a class IV item, in two sizes as follows:

United States standard gage	Thickness (inches)	Pounds per square foot ¹	Width (inches)	Length (feet)
28	0.015	0.68	27	8
22	.030	1.36	27	11

¹ Based on sheets 27 inches wide, lapped 8 inches.

b. Technical data on black and galvanized sheet metal with 2½-inch corrugations are given in table 15-3.

15-5. Wire Rope

a. *General.* Wire rope is manufactured from six types of metal and in many combinations of wire size, number of wires per strand, number of strands, and core types. Standard hoisting rope is made of 6 strands of 19 wires each, over a hemp core. It is flexible enough to operate over sheaves of practicable sizes. Using smaller wire sizes, ropes of 6 strands of 37 wires and of 8 strands of 19 wires are more flexible and permit smaller sheave sizes. Using larger wires, ropes of 6 strands of 7 wires are suitable for standing rope service, such as guys and moorings.

Table 15-3. Black and Galvanized Sheet Metal, 2½-Inch Corrugations

U.S. Standard gage	Thickness (inches)	Pounds per square foot ¹		Maximum span (feet)	
		Galvanized	Black	Roofing	Siding
28	0.015	0.85	0.68	2' 9"	3' 10"
26	.018	.99	.82	2' 9"	3' 10"
24	.024	1.26	1.09	3' 9"	4' 10"
22	.030	1.53	1.36	4' 9"	5' 10"
20	.036	1.81	1.64	5' 9"	5' 10"
18	.048	2.35	2.18	5' 9"	5' 10"
16	.060	2.90	2.73	5' 9"	5' 10"
14	.075	3.58	3.41	5' 9"	5' 10"
12	.105	4.94	4.77	5' 9"	5' 10"

¹ Based on sheets 27 inches wide, lapped 8 inches.

They require much larger sheaves if used over sheaves.

b. *Sheave Sizes.* Standard hoisting rope, 6 strands of 19 wires, requires a sheave diameter of 45 times the rope diameter to avoid excessive deterioration from bending stresses, and an absolute minimum sheave diameter of 30 times the rope diameter. Recommended and minimum sheave diameters for standard and other wire ropes are given in table 15-4.

c. *Breaking Strength.* While the breaking strength of wire rope varies slightly with the strand construction and number of strands, it

Table 15-4. Sheave Diameters for Wire Rope

Types of wire rope (strands by wires)	Recommended sheave or drum diameter	Minimum sheave or drum diameter
6 by 7	72 × rope diameter	42 × rope diameter.
6 by 19	45 × rope diameter	30 × rope diameter.
6 by 37	27 × rope diameter	18 × rope diameter.
8 by 19	31 × rope diameter	21 × rope diameter.

depends primarily upon the type of metal used. The breaking strength of standard 6 by 19 hoisting rope, given in table 15-5 for each type of metal, is about 10 percent higher than that of 6 by 7 standing rope and slightly lower than that of some of the more flexible wire ropes.

Table 15-5. Breaking Strength of Wire Rope

Diameter (inches)	Breaking strength in tons (6 by 19 wire rope)								
	¾	½	⅝	¾	⅞	1	1½	1¾	1½
Approximate weight per hundred feet (pounds)	23	40	63	90	123	160	203	250	360
Material									
Wrought iron	2.1	3.6	5.5	7.9	10.6	13.7	17.2	21.0	29.7
Traction steel	4.0	6.8	10.4	14.8	20.0	26.0	32.7	40.6	56.6
Cast steel	4.5	7.7	11.8	16.8	22.8	29.5	37.0	46.0	65.0
Mild plow steel	5.0	8.5	13.1	18.7	25.4	33.0	41.5	51.0	72.5
Plow steel	5.5	9.4	14.4	20.6	28.0	36.5	46.0	56.5	80.5
Improved plow steel	6.3	10.8	16.6	23.7	32.2	42.0	53.0	65.0	92.5

d. Safety Factors. The minimum safety factors for new wire rope in various types of service are given in table 15-6. These factors are increased for high-speed operation, impact, inadequate sheave diameters, for old or worn rope, or if the results of a failure would be exceptionally serious.

Table 15-6. Wire Rope Minimum Safety Factors

Type of service	Minimum safety factor
Track cables	3.2
Guys	3.5
Cable tools operating at depth in feet as shown:	
0 to 500	8.0
500 to 1000	7.0
2000 to 3000	5.0
3000 and over	4.0
Miscellaneous hoisting equipment	5.0
Haulage ropes	6.0
Derricks	6.0
Slings	8.0

b. Efficiency. Based on careful makeup, connection strengths are given in table 15-7 in percentages of the breaking strength of new wire rope. Basket sockets should be made up with zinc at 830° F, but the strength when made up with lead or babbitt metal is given for reference in case such sockets are found in use. The figures given are the maximum allowable and can be counted on only under ideal conditions.

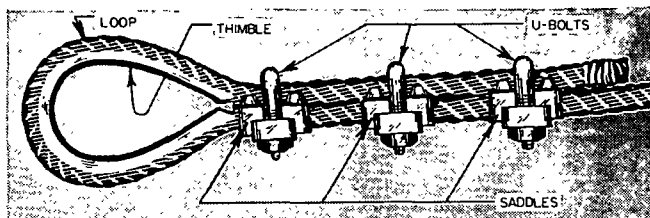


Figure 15-1. Wire rope clips and thimbles.

15-6. Wire Rope Accessories

a. Types. Clips (U-bolts and saddles) and thimbles are shown in figure 15-1; spliced loops and various types of sockets in figure 15-2.

15-7. Chains and Hooks

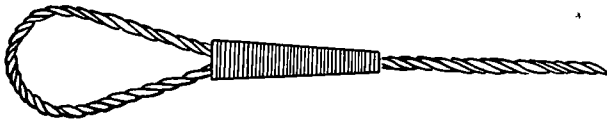
a. Chains. For typical straight-link chain, the safe load in tons is approximately eight times the square of the diameter in inches of the rod used to make the chain. If the type of metal used

Table 15-7. Wire-Rope Connections

Connection	Description	Maximum percent of strength of new wire rope
Three clips	See figure 15-1	80.
Basket sockets	Made with zinc at 830° F	80.
	Made with lead or babbitt metal	25 or more.
Thimble in spliced eye (fig. 15-2)	Rope diameter 1/4"	100.
	3/8"—3/4"	95.
	7/8"—1"	90.
	1 1/8"—1 1/2"	80.
	1 5/8"—2"	75.
	2 1/4" and up	70.

Table 15-8. Safe Loads on Chains

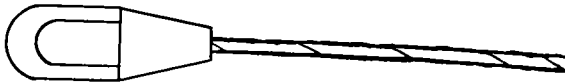
Dia of metal (inches)	Approximate weight per 100 feet, pounds	Safe load in tons			
		Wrought iron	High-grade wrought-iron	Soft steel	Special steel
3/8	160	1.35	1.49	1.65	3.20
7/16	210	1.73	1.90	2.18	4.15
1/2	280	2.25	2.48	2.63	5.25
5/8	430	3.47	3.81	4.23	7.60
3/4	630	5.07	5.58	6.00	10.50
7/8	840	7.00	7.70	8.25	14.33
1	1,100	9.30	10.23	10.60	18.20



LOOP



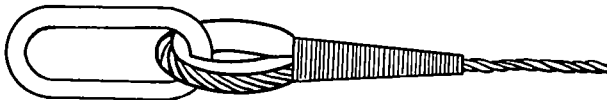
LOOP WITH THIMBLE



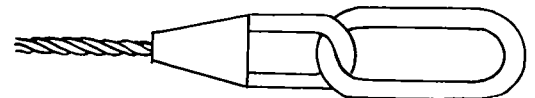
CLOSED SOCKET



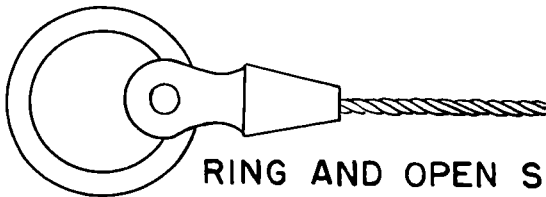
OPEN SOCKET



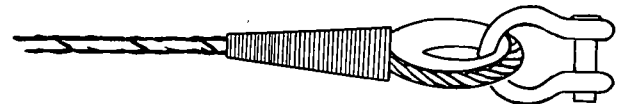
LINK AND THIMBLE



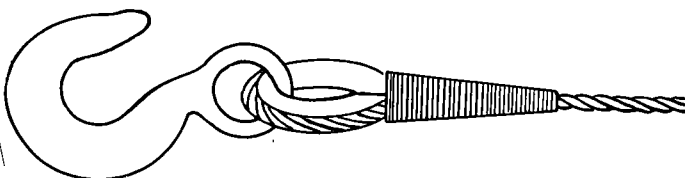
LINK AND CLOSED SOCKET



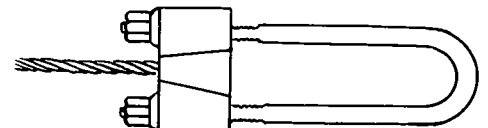
RING AND OPEN SOCKET



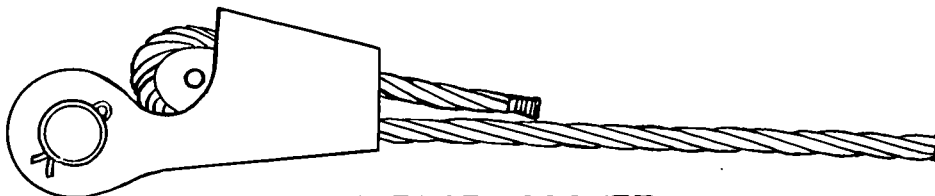
THIMBLE AND SHACKLE



HOOK AND THIMBLE



BRIDGE SOCKET



WEDGE - SOCKET CONNECTION

Figure 15-2. Wire-rope fittings.

in the chain is known, safe loads are given more accurately by table 15-8.

b. Hooks. The safe load in tons for hooks is approximately the square of the diameter in inches of the metal used to make the hook. Dimensions and safe loads for hooks are given more accurately in table 15-9.

15-8. Structural Steel

Working stresses, dimensions, weights, and other design properties of steel beams, channels, angles, and pipes will be found in paragraphs 14-13 through 14-18.

Table 15-9. Safe Loads on Hooks

Diameter of metal (inches)	Inside diameter of eye (inches)	Width of opening (inches)	Safe load (tons)
5/8 -----	3/4	1	0.5
11/16 -----	7/8	1 1/16	0.6
3/4 -----	1	1 1/8	0.7
7/8 -----	1 1/8	1 1/4	1.2
1 -----	1 1/4	1 3/8	1.7
1 1/8 -----	1 3/8	1 1/2	2.1
1 1/4 -----	1 1/2	1 11/16	2.5
1 3/8 -----	1 5/8	1 7/8	3.0
1 1/2 -----	1 3/4	2 1/16	4.0
1 5/8 -----	2	2 1/4	4.7
1 7/8 -----	2 1/8	2 1/2	5.5
2 1/4 -----	2 3/4	3	6.8
2 5/8 -----	3 1/8	3 3/8	8.5
3 -----	3 1/2	4	12.0

Section III. CONCRETE MATERIALS

15-9. Concrete Materials

a. Cement. In the United States, portland cement is shipped either in bulk or in paper or cloth bags holding 94 pounds, 1 cubic foot, loose measure. European portland cement is very similar to that made in the United States, but it is shipped in bags of 110 pounds and in some cases in wooden barrels.

b. Fine Aggregate. Fine aggregate consists of well-graded particles $\frac{1}{4}$ inch and smaller. Clay, silt, and dust should not exceed 3 percent by weight of the fine aggregate.

c. Coarse Aggregate. The commonly used coarse aggregates are gravel and crushed rock. They should consist of clean, hard, strong, and curable particles.

d. Water. Almost any water that is drinkable and has no pronounced taste or odor is satisfactory as mixing water for concrete. Whenever doubtful, concrete samples should be made and tested. Sea water may be used if fresh water is not available, but design allowance should be made for 10 to 20 percent less compressive strength in the concrete.

e. Reinforcing Rods. (See para 14-19—14-24.)

f. Average Weights of Materials Used in Con-

crete Construction. Concrete material weights are shown below.

Item	Average weight
Aggregate, coarse -----	2,500 pounds per cubic yard.
Aggregate, fine -----	2,800 pounds per cubic yard.
Aggregate, combined coarse and fine.	2,600 pounds per cubic yard.
Concrete -----	4,000 pounds per cubic yard.
Form lumber -----	3,000 pounds per thousand board measure.
Reinforcing steel, bundled ..	380 pounds per cubic foot.
Reinforcing steel -----	5 to 30 pounds per cubic yard of concrete.
Water -----	8.33 pounds per gallon.

g. Concrete Proportioning. Proportioning of concrete is covered in paragraphs 14-19 through 14-24. For large concrete projects, reference should be made to TM 5-742 or any reputable commercial textbook dealing with the subject.

15-10. Forms

Materials required and design details for wood forms for vertical construction are covered in paragraphs 14-19 through 14-24. For pavements, steel forms should be used when obtainable. Standard steel forms come in 10 foot lengths and vary between 8 and 12 inches in height. Locking plates rigidly join the ends of the sections and three steel stakes are required per each 10-foot section. Stakes are 1 inch in diameter and vary in length from 18 inches for 8-inch forms to 30 inches for 12-inch forms.

Section IV. BITUMINOUS CONSTRUCTION MATERIALS**15-11. Bituminous Materials**

Table 15-10 lists the principal asphalt and tar products used in paving, with their source, form in which marketed, grade designation, temperature of application, and other data.

15-12. Gradation and Quantity Requirements

Table 15-11 gives the gradation requirements for aggregates, quantities of aggregates and bituminous materials required per square yard for single, double, and triple surface treatments.

Table 15-10. Bituminous Materials

Material	Source	Form	Grade designation	Temperature of application		Remarks
				Spraying (°F)	Mixing * (°F)	
Cutback asphalts (RC and MC).	Product of refining crude petroleum oils containing asphalt.	Liquids, asphalt residues fluxed with more volatile petroleum distillates.	Rapid curing			Naphtha or gasoline (highly volatile), evaporating quickly and leaving asphalt cement binder. Permits early use of surface. Inflammable. Keep open flame away from storage tanks and drums. Flash point is 80° F (+) for each grade.
			RC-70	105-180	90-135	
			RC-250	145-220	135-175	
			RC-800	180-255	170-210	
			RC-3000	215-290	200-240	
			Medium curing			Kerosene (less volatile) does not evaporate so quickly and cures more slowly than RC types. Inflammable. Keep open flame away from storage tanks and drums. Flash point is 100° F (+) for grades MC-250, MC-800 and MC-3000.
			MC-30	70-145	50-170	
			MC-70	105-180	90-135	
			MC-250	145-220	135-175	
			MC-800	180-255	170-210	
MC-3000	215-290	200-240				
Asphalt road oils (SC).	Products of refining crude petroleum oils containing asphalt.	Liquids, low, volatile oils left or blended with asphalt residues near end of refining process.	Slow curing			Slow curing. Flash point is 150° F (+) for grade SC-70; 175° F (+) for grades SC-250 and SC-800; and 225° F (+) for grade SC-3000.
			SC-70	50-120	90-135	
			SC-250	80-125	135-175	
			SC-800	150-200	170-210	
			SC-3000	175-250	200-240	
Asphaltic cements (AC) or paving asphalts.	Products of refining crude petroleum oils containing asphalt.	Semi-liquids or solids.	For open-grade mixes			Penetration 40 to 100 used for crack and joint fillers. Penetrations 70 to 300 used for plant mixes, penetration macadam, and surface treatment. Comparable grades, Federal Specification CC-A-706b: 50-60 penetration, AP-3; 100-120 penetration, AP-2; 125-150 penetration, AP-1.
			¹ 40-50	300-410	225-310	
			¹ 60-70	295-405	225-305	
			¹ 85-100	290-400	225-300	
			¹ 120-150	285-395	225-300	
			¹ 200-300	275-385	225-300	
			For dense-grade mixes			
			¹ 40-50	300-410	275-340	
			¹ 60-70	295-405	265-330	
			¹ 85-100	290-400	255-320	
¹ 120-150	285-395	245-310				
¹ 200-300	275-385	235-300				
Powdered asphalt (PA).	-----do-----	Hard and solid asphalts ground to powder.				Used with SC oils to produce extra tough road surfaces.
Asphalt emulsions (AE)	Asphalt cements in water with	Liquids -----	Rapid, medium, and slow setting			Freezing destroys emulsion, penetration, and surface treatments. Road and plant mixes with coarse aggregate. Road and plant mixes with fine aggregate. Grades and typical uses of asphalt emulsions under Federal Specification SS-A-674a are as follows:
			RS-1	75-130	**	
			RS-2	110-160	**	

	an emulsifying agent.		MS-2 SS-1 SS-1h RS-2k RS-3k CM-k SM-k SS-k SS-k	100-160 75-130 75-130 75-130 110-160 100-160 100-160 75-130 75-130	50-140 50-140 50-140 ** ** 50-140 50-140 50-140 50-140	Grade I, Surface treatments, seal coats. Grade II, Open-graded coarse aggregate mixed-in-place. Grade III, Summer use in bituminous concrete mixtures for repair work. Grade IV, Winter use in bituminous concrete mixtures for repair work. Grade V, Penetration macadam and surface treatments. Grade VI, Fine aggregate mixes in which a substantial quantity of aggregate passes 1/8-inch sieve and a portion may pass a No. 200 sieve.
			Rapid, medium, and slow setting			
Road tar (RT) priming oils.	All road tars are refined byproducts of coking coal or manufacture of water gas.	Liquids -----	RT-1 RT-1 RT-3	60°-125° 60°-125° 80°-150°	-----	Priming oils.
Cold tars (TC) -----	-----do-----	-----do-----	RT-4 RT-5 RT-6 RT-7	80°-150° 80°-150° 80°-150° 150°-225°	-----	Cold tars for road mix and patching.
Hot tars (TH) -----	-----do-----	Nonliquids -----	RT-8 RT-9 RT-10 RT-11 RT-12	150°-225° 150°-225° 175°-250° 175°-250° 175°-250°	-----	Hot tars for plant mix, seal coats, penetration macadam, crack fillers, etc.
Cuthack tars (RTCB).	Tars combined with volatile distillates from coal- or-water-gas tar.	Liquids -----	RTCB-5 RTCB-6	60°-250° 60°-120°	-----	Patching mixtures. Inflammable. Keep open flame away from storage tanks and drums.
Rock asphalt -----	Natural combinations of asphalt with sand or stone.	Solids -----	-----	-----	-----	Mined and used locally where found with cutbacks added if needed.

* Temperature at which asphalt should be introduced into the mix.

** Not used for mixing.

¹ Penetrations of 100, 120, 150, 200, and 300 show increasing of fluidity. Penetrations of 85, 70, 60, 50, 40, and so on, show increasing hardness of solidity. Road oil SC5 (with high viscosity) and the softest paving asphalts both have penetrations of about 200.

Table 15-11. Gradation and Quantity Requirements

Line No.	Size of aggregate	Pounds of aggregate per sq yd	1 3	Hot weather (80°F+)		Cool weather (up to 80°F)	
				Hard aggregate	Absorbent aggregate	Hard aggregate	Absorbent aggregate
1	¾ to ⅝	40-50	.40-.50	120-150 RC3000, RS2, RS-2K, RS-3K	RC3000, RS2, RS-2K, RS-3K	RC800, RS2, RS-2K, RS-3K	RC800, RS2, RS-2K, RS-3K
2	½ to No. 4	25-30	.25-.30	200-300 * RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K
3	⅝ to No. 8	15-20	.15-.20	RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K
4	¼ to No. 8	10-15	.10-.15	RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K,	RC250,800, RS1, RS2, RS-2K, RS-3K	RC250,800, RS1, RS2, RS-2K, RS-3K
5	Sand	10-15	.10-.15	RC250,800, RS1, RS2, RS-2K, RS-3K, SS-1, SS-K	RC250, 800, RS1, RS2, RS2K, RS-3K, SS-1, SS-K	RC250,800, RS1, RS-2K, RS-3K, SS-1, SS-K	RC250,800, RS1, RS-2K, RS-3K, SS-1, SS-K

* These quantities and types of materials may be varied according to local conditions and experience.

¹ The lower application rates of asphalt shown in the table should be used for aggregate having gradings on the fine side of the limits specified. The higher application rates should be used for aggregate having gradings on the coarse side of the limits specified.

² The weight of aggregate shown in the table is based on aggregate with a specific gravity of 2.65. In case the specific gravity of the aggregate used is less than 2.55 or more than 2.75 the amount shown in the table above should be multiplied by the ratio which the bulk specific gravity of the aggregate used bears to 2.65.

³ Under certain conditions, the heavier grades of MC liquid asphalts may be used in cool weather.

⁴ In some areas persistent difficulty in retaining aggregate has been experienced with 200-300 penetration asphalt cements. Where this has occurred, the use of 200-300 penetration asphalt cements is not recommended.

Notes:

Single Surface Treatments. The maximum size aggregate should not be over ½ inch. Use line 2. For lighter surface treatments, use line 3 or 4; however, lines 3 and 4 are more for light seal coats. For sand seals use line 5.

Double Surface Treatments. The maximum size can be up to ¾ inch. First course, use line 1; second course, use line 3 or 4. For lighter double surface treatments use for first course, line 2; for second course, line 3 or 4.

Triple Surface Treatments. The maximum size aggregate is usually ¾ inch. The following is recommended; first course, line 1; second course, line 2; third course, line 3 or 4. For most situations, the best probably is lines 1, 2, and 4 for the three courses.

Section V. MASONRY

15-13. Stone Masonry

a. Ashlar. This is the best type of stone masonry and the type used for work requiring great strength and stability. It is characterized by carefully bonded and fitted stones set on level beds and laid with joints varying from ⅛ to ¼ inch thick for architectural work and from ¼ to ½ inch thick for railroad masonry.

b. Squared-Stone Masonry. Usually constructed as broken-course work, this type is fitted less carefully than ashlar, more carefully than rubble. Well-built squared-stone masonry normally includes the highest types used in military construction.

c. Rubble. Rubble masonry is built with a minimum of dressing, with joints unevenly coursed, or in a completely irregular pattern. Stones are lapped for bond and many stones extend through

a wall to bond it transversely. If built carefully, with all interstices completely filled with good cement mortar and bedded spalls, rubble masonry has ample strength and durability for ordinary structures.

15-14. Brick Masonry

a. Types of Brick.

(1) *Common brick*, normally 8 by 3¾ by 2⅝ inches, are used in all brickwork unless other types are specifically mentioned. They are typically kiln-burned clay or clay-and-shale mixtures, but are also made of a sand-lime combination, steam cured, or of sand and portland cement, moist cured.

(2) *Vitrified paving brick and paving blocks*, very hard and durable, are used in any structure in which these qualities are required.

(3) *Firebrick*, laid in a thin grout of fire clay, are used in furnace linings and other refractory service.

b. Brick Quantities. In common brick masonry, about $6\frac{3}{4}$ brick are required per square foot of wall 1 brick in thickness; 20 brick per cubic foot of masonry.

c. Rate of Laying Brick. A skilled bricklayer can lay 1,200 or more bricks per 8-hour day in straight walls 3 bricks or more in thickness; 200 to 600 bricks in thinner walls or in work having many corners, angles, or openings. These maximum rates are not normally attained in peacetime construction in this country.

15-15. Hollow-Tile and Concrete-Block Masonry

These materials are used in lightweight walls and partitions to provide thicknesses necessary for stability or to provide stable backing for 4-inch brick facing. Usual sizes and types are as follows:

a. Hollow Tile.

(1) For backup and bearing-wall purposes, many sizes and types have been developed, typically to provide hollow-tile wall thicknesses of 8 inches and 12 inches. A common type is the 6-cell hollow tile 8 by 12 inches, weighing about 36 pounds. It can be used for walls of either 8- or 12-inch thickness.

(2) For partitions, 3-cell tile with 12- by 12-inch faces are made for 3-, 4-, and 6-inch wall thicknesses.

b. Concrete Blocks. These are typically 12 or 16 inches long, 8 inches high, and made for wall thicknesses of 4, 8, and 12 inches. Walls 12

inches thick are used for foundation walls for light structures, the 8-inch thickness for exterior walls above grade and for piers, and the 4-inch thickness for partitions.

15-16. Unit Weights

	Weight in pounds per cubic foot
Squared-stone masonry	150 to 170
Rubble-stone masonry	130 to 155
Brick masonry	125 to 140
Hollow-tile or concrete-block masonry	40 to 70

15-17. Mortar

For mortar, one part cement-lime mixture is mixed with $2\frac{1}{4}$ to 3 parts sand by volume, measured in the loose damp condition. For 1 cubic yard of 1:3 cement mortar, with one to nine cement-lime ratio, about 880 pounds of portland cement and 40 pounds of hydrated lime are added to 1 cubic yard of sand, damp and loose measure. More sand, up to a total of 2 cubic yards, is added if less strength is needed. For a 1-bag batch, the usual quantities are 94 pounds of cement, 5 pounds of hydrated lime, and 3 to 5 cubic feet of sand. The number of cubic yards of mortar per hundred square feet of wall of various material are as follows:

	Wall thickness (inches)			
	4	8	12	18
Rubblestone	-----	-----	-----	0.8
Common brick	0.3	0.7	1.2	-----
Hollow tile or concrete blocks	.14	.23	.36	-----

Strength characteristics can be varied by varying the amount of lime in the mortar. The following tabulation illustrates this.

Mortar type	Compressive strength *	Proportions by volume		
		Cement	Hydrated lime or lime putty range	Aggregate measured in damp loose condition
M	2500	1	0 to $\frac{1}{4}$	Not less than $2\frac{1}{4}$ and not more than 3 times the sum of the cement and lime used.
S	1800	1	$\frac{1}{4}$ to $\frac{1}{2}$	
N	750	1	$\frac{1}{2}$ to $1\frac{1}{4}$	
O	350	1	$1\frac{1}{4}$ to $2\frac{1}{2}$	
K	75	1	$2\frac{1}{2}$ to 4	

* Minimum for 2" cubes at 28 days.

Section VI. MISCELLANEOUS BUILDING MATERIALS AND HARDWARE

15-18. Wallboard, Insulation: Substitutes

Nomenclature, sizes, types and logistical data are given in table 15-12. Data on lumber are given in paragraphs 14-25 through 14-32.

15-19. Nails, Types and Quantities

Table 15-13 gives types and sizes of nails, common use, number per pound, and guidance for estimating quantities required. When using the

Table 15-12. Logistical Data, Wallboard and Other Building Materials

	Sizes			Unit measure	Units per container	Type of container	One filled container		Common names
	Thick-ness	Width	Length				Weight (pounds)	Cubic feet	
Board, masonite, tempered ..	$\frac{1}{4}$ "	48"	96"	Sheet ----	50	Box ----	3,520	116.28	Hardboard. Tempered masonite.
	$\frac{1}{4}$ "	48"	144"	Sheet ----	5	Case ----	450	13.62	
Cement, bituminous plastic, asphaltic base.	1 lb can -----			Pound ----	1	Can ----	1	0.23	Roof cement.
	50 lb can -----			Pound ----	50	Can ----	53	1.08	
Felt, roofing, asphalt saturated, 15 lb, Type I.	-----	36"	144"	Roll ----	3	Crate --	217	8.06	Tarpaper. Roofing felt.
Fiber board, insulating, roof board, Class C.	$\frac{1}{2}$ "	48"	96"	Sheet ----	6	Crate --	218	15.21	Roof insula- tion.
	$\frac{1}{2}$ "	48"	120"	Sheet ----	6	Crate --	235	21.96	Wallboard.
	$\frac{1}{2}$ "	48"	144"	Sheet ----	14	Box ----	662	39.05	Celotex.
Glass substitute, reinforced..	-----	36"	100'	Square yard.	33 $\frac{1}{3}$	Carton -	43	0.93	
	-----	48"	198'	Square yard.	88	Box ----	160	5.58	
Roof coating, asphalt, fibrous, brushing consistency.	5 gal can -----			Gallon ---	5	Can ----	43	1.08	Roof paint.
	50 gal drum -----			Gallon ---	50	Drum --	485	11.67	
Wallboard, composition.	$\frac{3}{8}$ "	48"	96"	Sheet ----			41	-----	Wallboard. Insulating board.

¹ Weight per sheet, uncrated.

Engineer Functional Components System, quantity of nails required is given by the following formulas:

$$\text{No. of lbs} = \frac{d \times \text{BF}}{400}; \text{ less than 2" material (sheathing, flooring) (2d to 12d nails)}$$

$$\text{No. of lbs} = \frac{d \times \text{BF}}{600}; \text{ 2" or greater material (framing) (12d to 60d nails)}$$

Where: BF = board feet
d = pennyweight nail

15-20. Screws and Bolts

Table 15-14 gives the size number, gage, and length of wood screws. Table 15-15 gives the length, diameter, and length of threaded portion of lag screws. Table 15-16 gives data on Bolts, Machine, American Standard Regular.

Sizes and Kinds of Material	Sizes	Length in inches,	Approx. no. per lbs.	Pounds per MRF on center as follows:			
				12"	16"	36"	48"
1 x 4	8d common	2 1/2	106	60	48	23	20
1 x 6	8d common	2 1/2	106	40	32	16	18
1 x 8	8d common	2 1/2	106	31	27	12	10
1 x 10	8d common	2 1/2	106	25	20	10	8
1 x 12	8d common	2 1/2	106	31	24	12	10
2 x 4	20d common	4	29	105	80	60	33
2 x 6	20d common	4	29	70	54	27	22
2 x 8	20d common	4	29	53	40	21	17
2 x 10	20d common	4	29	60	50	25	20
2 x 12	20d common	4	29	52	41	21	17
3 x 4	60d common	6	11	197	150	76	61
3 x 6	60d common	6	11	131	97	52	42
3 x 8	60d common	6	11	100	76	38	34
3 x 10	60d common	6	11	178	137	70	55
3 x 12	60d common	6	11	145	115	53	46
Base, per 100 ft. lin.	8d finish	2 1/2	189	---	1	--	--
Ceiling, 3/4 x 4	8d finish	2 1/2	189	18	14	--	--
Ceiling, 1/2 and 5/8	6d finish	2	309	11	8	--	--
Finish, 7/8	8d finish	2 1/2	189	25	12	--	--
Finish, 1 1/8	10d finish	3	121	12	10	--	--
Flooring, 1 x 3	8d floor brads	2 1/2	99	42	32	--	--
Flooring, 1 x 4	8d floor brads	2 1/2	99	32	26	--	--
Flooring, 1 x 6	8d floor brads	2 1/2	99	22	18	--	--
Framing, 2 x 4 to 2 x 16	20d common	4	29	20	16	--	--
requires 3 or more sizes and vary greatly	16d common	3 1/2	46	10	10	--	--
	10d common	3	74	8	6	--	--
Framing, 3 x 4 to 3 x 14	60d common	6	11	30	25	--	--
Siding, drop, 1 x 4	8d casing	2 1/2	145	45	35	--	--
Siding, drop, 1 x 6	8d casing	2 1/2	145	30	25	--	--
Siding, drop, 1 x 8	8d casing	2 1/2	145	23	18	--	--
Siding, bevel, 1/2 x 4	6d finish	2	309	23	18	--	--
Siding, bevel, 1/2 x 6	6d finish	2	309	15	13	--	--
Siding, bevel, 1/2 x 8	6d finish	2	309	12	10	--	--
Casing, per opening	6d and 8d casing			About 1/2 pound per side.			
Flooring, 3/8 x 2	3d brads	1 1/4	568	About 10 pounds per 1000 square feet. (12" o.c.)			
Lath, 48"	3d fine	1 1/8	778	6 pounds per 1000 pieces. (16" o.c.)			
Ready roofing	Barbed roofing	7/8	469	3/4 of a pound to the square. (2" o.c.)			
Ready roofing (5/8 heads)	American felt roofing	7/8	180	1 1/2 pounds to the square. (2" o.c.)			
Shingles*	3d shingle	1 1/4	420	4 1/2 pounds; about 2 nails to each 4 inches.			
Shingles	4d shingle	1 1/2	274	7 1/2 pounds; about 2 nails to each 4 inches.			
Shingles	American felt roofing	7/8	180	12 lbs, 5/8" heads; 4 nails to shingle.			
Shingles	Barbed roofing	7/8	469	4 1/2 lbs, 5/8" heads; 4 nails to shingle.			
Wall board, around entire edge	2d Barbed Berry, flat head	1	1150	5 pounds, 5/8" heads; per 1000 square feet.			
Wall board, intermediate nailings	2d casing or floor brad	1	1010	2 1/2 lbs, 5/8" heads; per 1000 square feet.			

*Wood shingles vary in width but are usually 8 inches wide. Regardless of width 1000 shingles are the equivalent of 1000 pieces 4 inches wide.

Table 15-13. Wire Nails—Kinds and Quantities Required

Table 15-14. Screw Sizes and Dimensions

Length (in.)	Size numbers																														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24	26	28	30						
¼	x	x	x	x																											
⅜	x	x	x	x	x	x	x	x	x	x																					
½		x	x	x	x	x	x	x	x	x	x	x	x	x	x																
⅝			x	x	x	x	x	x	x	x	x	x	x	x	x																
¾				x	x	x	x	x	x	x	x	x	x	x	x	x	x														
7⁄8				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x													
1					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x											
1¼						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x									
1½						x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
1¾							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
2							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
2¼								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
2½								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
2¾									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
3									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
3½										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
4											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
4½												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
5													x				x			x	x	x	x	x	x	x	x	x	x		
6																x			x			x	x	x	x	x	x	x	x		
Gage and diameter																															
Steel wire gage																															
Diameter (inches)		17	15	14	13	12	11	10	9	8	7	6½	6	5																	
		.054	.072	.080	.091	.105	.120	.135	.148	.162	.177	.184	.192	.207																	
Steel wire gage																															
Diameter (inches)		4½	4	3	2½	2	1	½	0	00	00½	000	0000																		
		.216	.225	.243	.253	.262	.283	—	.306	.331	—	.362	.393																		

Table 15-15. Lag Screws

Lag screw lengths, inches ¹	Lag screw diameters								
	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
2 and 2 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	—	—	—
2 1/2 and 2 3/4	1 1/2	1 5/8	1 5/8	1 3/4	1 3/4	1 3/4	—	—	—
3 and 3 1/2	2	2	2	2	2	2	2	2	2
4 and 4 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2
5 and 5 1/2	3	3	3	3	3	3	3	3	3
6 and 6 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2
7 and 7 1/2	4	4	4	4	4	4	4	4	4
8 and 8 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2	4 1/2
9 and 9 1/2	5	5	5	5	5	5	5	5	5
10	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4	5 1/4
11	—	—	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2	5 1/2
12	—	—	6	6	6	6	6	6	6
13	—	—	—	—	6 1/2	6 1/2	6 1/2	6 1/2	6 1/2
14	—	—	—	—	7	7	7	7	7
15	—	—	—	—	7 1/2	7 1/2	7 1/2	7 1/2	7 1/2
16	—	—	—	—	8	8	8	8	8

¹ Measured from underside of head to point.

Table 15-16. Bolt Sizes and Threads

Bolt (inches)	Number of threads per inch ¹	Diameter at root of thread (inches)	Area at root of thread (square inches)	Short diameter of square head (inches)	Short diameter of nut (square or hexagon) (inches)	Height of nut (inches)
1/4	20	0.185	0.027	3/8	7/16	1/4
3/8	16	.294	.068	9/16	5/8	5/16
1/2	13	.400	.126	3/4	13/16	7/16
5/8	11	.507	.202	15/16	1	9/16
3/4	10	.620	.302	1 1/8	1 1/8	11/16
7/8	9	.731	.419	5 5/16	1 5/16	3/4
1	8	.838	.551	1 1/2	1 1/2	7/8
1 1/8	7	.939	.693	1 11/16	1 11/16	1
1 1/4	7	1.064	.890	1 7/8	1 7/8	1 1/8
1 3/8	6	1.158	1.054	2 1/16	2 1/16	1 1/4
1 1/2	6	1.283	1.294	2 1/4	2 1/4	1 5/16
1 5/8				2 7/16	2 9/16	1 5/8
1 3/4	5	1.490	1.744	2 5/8	2 3/4	1 3/4
1 7/8				2 13/16	2 15/16	1 7/8
2	4 1/2	1.711	2.300	3	3 1/8	2
2 1/4	4 1/2	1.961	3.031	3 3/8	3 1/2	2 1/4
2 1/2	4	2.175	3.716	3 3/4	3 7/8	2 1/2
2 3/4	4	2.425	4.619	4 1/8	4 1/4	2 3/4
3	4	2.675	5.621	4 1/2	4 5/8	3

¹ American National Form screw threads.

Section VII. ROCKS

15-21. Introduction

Rocks occur over large parts of the earth's surface and are used extensively by Army engineers as construction material. It is, therefore, important that the engineer be able to identify rocks and understand their value as construction materials. This section includes only general information. If more detail is required, refer to TM 5-545.

15-22. Groups And Origin

Rocks are classified into three large groups: *igneous*, *sedimentary*, and *metamorphic*.

a. Igneous rocks are formed by the cooling and crystallization of molten rock called *magma*. Igneous rocks are called *intrusive* if they cooled and solidified beneath the earth's surface. In this case the magma cools and solidifies slowly, resulting in a rock with coarse mineral grains. *Extrusive* igneous rocks are formed by the rapid cooling of magma on the earth's surface, producing fine-grained rocks such as basalt.

Igneous rocks are classified by their chemical composition and their *texture*, which is the size, shape, and arrangement of the mineral grains.

The chemical composition of igneous rocks is indicated by their *color*. Light-colored rocks con-

tain more than 50 percent silica (SiO_2); dark-colored rocks contain less than 50 percent silica. Table 15-17 gives a classification of igneous rocks based upon their texture and color. Also shown are the values of the rocks as construction materials.

b. Sedimentary rocks consist of the accumulated products of weathering. They are composed of hardened or cemented layers of sand, silt, clay, or lime. There are two major types of sedimentary rocks: *chemical sediments*, formed from material that has been transported as particles in some fluid (air, water, ice) and later deposited. Limestone and dolomite are examples of chemical sedimentary rocks. Conglomerate, sandstone, and shale are examples of clastic sedimentary rocks. Table 15-18 gives a classification of the sedimentary rocks based upon their type, grain size, and composition.

c. Metamorphic rocks are formed from pre-existing rocks (igneous, sedimentary, or metamorphic) which have had their composition and/or their texture altered by heat, pressure, and chemically active fluids deep within the earth's crust. Metamorphic rocks are divided into two types: *foliated* and *nonfoliated*. Foliated metamorphic rocks display textures consisting of the parallel arrangement of platy or needle-like

Table 15-17. *Igneous Rock Classification*

Texture \ Color	Light colored (white, red, pink)	Dark colored (black, green, grey)	Use
Coarse	Granite	Gabbro-diorite	Good aggregate
Fine	Felsite	Basalt	Good aggregate
Glassy	Obsidian	Basaltic glass	Poor construction material
Scoriaceous (bubbly)	Pumice	Scoria	Use as lightweight aggregate or as insulating material. Do not use for loadbearing structures.
Fragmental	Ash	Ash	If fused, might be useful as aggregate. Otherwise use- less.

Table 15-18. *Sedimentary Rock Classification*

Type	Characteristics		Rock	Use
CLASTIC (rock particles)	50% of grains larger than 2 mm.	rounded	conglomerate	Highly variable quality, usually poor.
		angular	breccia	
	Sand-sized grains. Rock breaks around grains.		Sandstone	For fine or coarse aggregate, de- pending upon cementation.
	Clay- and silt-sized particles. Breaks into plates		Shale	Poor construction material.
Pyroclastic	Light weight Often shows layering		Tuff	Poor construction material.
Chemical or Bio- chemical	Reacts with 10% HCl Dense texture		Limestone	Excellent construction material.
	Reacts with 10% HCl Loosely packed shell fragments.		Coquina	Poor construction material.
	Reacts with 10% HCl only when powdered dense texture.		Dolomite	Excellent construction material.
	Very hard, brittle Cuts glass		Chert	Poor as road aggregate. <i>DO NOT</i> <i>use in concrete.</i>
Chemical residues.	Black or dark reddish, brown hy- drated oxides of iron and alum- inum.		Laterite	Good for road aggregate. Hardens with alternate wetting and drying.

mineral grains. Nonfoliated metamorphic rocks are massive and have no such texture. Table 15-19 lists the common metamorphic rocks and their

classification, based upon their composition and degree of foliation. Also shown are the values of the rocks as construction materials.

Table 15-19. Metamorphic Rock Classification

Foliated

Degree of foliation	Texture	Characteristics	Rock	Use
Poor	Coarse, banded	Streaked or banded	Gneiss	Good aggregate
Medium	Medium-grained	Rich in mica, splits easily	Schist	Poor construction material
Excellent	Fine-grained	Splits easily into smooth sheets	Slate	Poor construction material

Non-foliated

Mineral Content	Characteristics	Rock	Use
Chiefly quartz, some others	Hard, breaks across mineral grains.	Quartzite	Good construction material, but expensive to quarry.
Chiefly calcite or dolomite	Reacts with 10% HCl	Marble	Excellent, as good as limestone.



CHAPTER 16

CONSTRUCTION PLANNING FACTORS

Section I. DEFINITION AND SCOPE

16-1. Introduction

This chapter provides some of the planning factors most frequently needed in theater of operations type construction. Included are tabulations indicating facility and supply requirements for troops, manpower effort requirements for various tasks, and equipment production rates.

16-2. References

TM 5-333 covers construction management in detail including the network analysis systems, Critical Path Method (CPM), and Program Evaluation Review Technique (PERT). It also includes extracts from TM 5-301, TM 5-302 and TM 5-303, covering the purpose and application of the Engineer Functional Components System. The TM 5-331 series (A through E) deals with the utilization of engineer construction equipment. FM 101-10-1 also includes logistical and planning data. Technical manuals on specific subjects, such as TM 5-343, Military Petroleum Pipeline Systems, contain more comprehensive planning information and should be referred to for major construction projects.

16-3. Battalion Month

Tables used in this section indicate man-hours of

effort required to construct certain facilities. As a measure of man-hours of effort available, 1 battalion month is considered to be the construction effort of an average experienced, full strength, and properly equipped engineer construction battalion working 10-hour days, 6 days a week for 1 month. For general estimates the battalion month represents 125,000 man-hours of construction effort. This should be used as a planning guide only and modified when conditions indicate. Table 16-1 will be of some assistance in modifying man-hour effort available for different units and between the combat zone and COMMZ. TM 5-301 contains more extensive tables and information on man-hour requirements for engineer construction projects, including a breakdown between skilled and unskilled labor requirements.

Table 16-1. Construction Effort Factors

1	Unit	Average construction effort factor	
		2	3
		Combat Zone	COMMZ
2	Engr Construction Battalion ----	1.0	1.0
3	Engr cbt bn -----	1.3	0.6
4	Engr cbt bn plus LE co -----	1.4	0.9
5	Engr CB plus const spt co -----	1.2	1.4

Section II. TABLES

16-4. Standards of Construction

a. Camp Requirements. Table 16-2 gives troop camp construction requirements. Structures are prefabricated steel frame or wood frame. Depending upon degree of permanence of the camp, requirements are based upon six standards, as follows:

(1) *Standard 1.* Table of organization and equipment (TOE) tents; no engineer materials or effort involved.

(2) *Standard 2.* Class IV tents pitched by using troops; engineer effort for roads and site preparation.

(3) *Standard 3.* Buildings with floors for administration, bathhouses, and kitchens. Class IV tents with floors for housing and with earthen floors for all other purposes. Roads within the installations stabilized with local materials. Water piped from central storage tank to infirmaries, bathhouses, and kitchens. Electric distribution to buildings. Pit-type latrines.

(4) *Standard 4.* Buildings with floors for all purposes except housing, for which there are class IV tents with floors and wood frames. Roads within the installations stabilized with local materials. Water piped from central storage tank to infirmaries, bathhouses, kitchens, and camp exchange. Electric distribution to all facilities. Pit-type latrines.

(5) *Standard 5.* Buildings with floors for all purposes; otherwise the same as standard 4 above.

(6) *Standard 6.* Water piped from central storage tank to latrines; latrines equipped so that waterborne, untreated sewage carried 300 meters beyond the confines of the camp; bituminous surfacing of roads within the installations; otherwise, the same as standard 5 above.

b. Hospital Requirements. Table 16-3 gives construction requirements for 100 to 1,000 bed hospitals, based upon four different standards as follows:

(1) *Standard 2.* Facilities in class IV tents with some buildings (clinic, latrines, building for servicing ward patients); hospital tents framed; personnel tents pitched by using troops with no engineer material or assistance. Water

pipled from central storage tank to necessary facilities. Concrete floors for tentage with frames and for buildings. Waterborne sewage in buildings and pit latrines for other facilities. Roads unimproved. Electric distribution to all facilities.

(2) *Standard 3.* Same as standard 2, except that all sewage waterborne, roads stabilized, and additional buildings provided.

(3) *Standard 4.* Same as standard 3, except that all tents framed and floored and additional buildings provided.

(4) *Standard 6.* Same as standard 4, except that buildings provided for all facilities and roads bituminous surfaced.

c. Administrative Requirements. Table 16-4 gives construction requirements for administrative facilities based upon standards 3, 4, and 6 of troop camp standards as defined above. Structures are primarily prefabricated.

d. Training Area Requirements. Table 16-5 gives training area requirements for various units. Strength figures include supporting troops, i.e., aggregate strength.

e. Depots. Tables 16-6, 16-7, and 16-8 give

Table 16-2. Troop Camp Construction Requirements *

	1	2	3	4	5	6	7	8	9	10	11
1	Standard	Size (number of men)	Electric (kw)	Water (M gal per day)	Site area (sq m)	With steel-frame buildings			With wood-frame buildings		
						STON	MTON	Man-hours	STON	MTON	Man-hours
2	1-----	Organic tents—no engineer materials or effort required.									
3	2-----	Class IV quartermaster tents erected by using service. Engineer effort required for roads and site preparation.									
4	3-----	250	2.2	3.75	31,155	89	128	7,570	103	130	8,090
5	-----	500	7.9	7.50	80,000	166	239	13,740	192	241	14,840
6	-----	1,000	12.6	15.00	164,610	322	451	28,690	366	463	30,900
7	-----	1,500	15.4	22.50	208,000	456	634	39,555	518	650	42,715
8	-----	3,000	27.0	45.00	424,000	825	1,149	72,120	939	1,177	77,900
9	4-----	250	5.4	3.75	31,155	142	199	11,070	159	201	11,860
10	-----	500	17.3	7.50	80,000	297	431	23,120	440	572	25,240
11	-----	1,000	31.6	15.00	164,610	563	800	44,250	633	840	48,200
12	-----	1,500	39.4	22.50	208,000	782	1,076	61,240	877	1,101	65,590
13	-----	3,000	78.0	45.00	424,000	1,488	2,092	118,180	1,672	2,106	128,830
14	5-----	250	5.5	3.75	31,155	195	296	13,590	228	392	15,910
15	-----	500	17.3	7.50	80,000	401	607	27,890	477	613	32,670
16	-----	1,000	31.3	15.00	164,610	764	1,155	53,260	897	1,145	62,590
17	-----	1,500	39.1	22.50	208,000	1,072	1,626	73,030	1,242	1,597	86,490
18	-----	3,000	77.5	45.00	424,000	2,103	3,181	141,970	2,441	3,108	169,210
19	6-----	250	5.5	6.25	31,155	204	308	14,650	233	301	16,290
20	-----	500	17.4	12.50	64,550	423	637	28,270	491	632	33,080
21	-----	1,000	31.4	25.00	164,610	808	1,221	53,140	929	1,182	62,330
22	-----	1,500	39.0	37.50	208,000	1,143	1,718	73,900	1,311	1,662	87,810
23	-----	3,000	78.4	75.00	424,000	2,268	3,407	145,640	2,607	3,303	172,440

* Does not include fortifications.

Table 16-3. Hospital Construction Requirements

	1	2	3	4	5	6	7	8	9	10	11
1	Standard	Size (beds)	Electric (kw)	Water (M gal per day)	Site area (sq m)	With steel-frame buildings			With wood-frame buildings		
						STON	MTON	Man-hours	STON	MTON	Man-hours
2	2	100	81.2	5.0	40,470	331	521	29,050	351	502	30,860
3		200	104.1	10.0	54,500	441	687	38,530	462	665	39,254
4		300	146.0	15.0	74,500	649	1,004	60,950	690	967	60,480
5		500	193.9	25.0	100,000	833	1,300	77,670	884	1,255	79,070
6		750	248.0	37.5	128,500	1,072	1,627	98,720	1,136	1,579	100,670
7		1,000	276.0	50.0	157,500	1,254	1,904	111,820	1,331	1,840	115,990
8	3	100	111.0	5.0	40,470	544	874	52,050	585	829	51,780
9		200	184.3	10.0	54,500	788	1,237	71,825	863	1,134	72,185
10		300	246.0	15.0	74,500	1,074	1,748	99,740	1,194	1,664	103,370
11		500	309.0	25.0	100,000	1,317	2,271	123,690	1,528	2,150	133,150
12		750	407.0	37.5	128,500	1,523	2,648	165,360	1,994	2,808	170,430
13		1,000	503.0	50.0	157,500	2,192	3,512	182,840	2,383	3,361	189,120
14	4	100	135.0	5.0	40,470	703	1,149	64,740	771	1,090	66,760
15		200	194.7	10.0	54,500	888	1,553	83,530	1,054	1,478	86,990
16		300	285.8	15.0	74,500	1,341	2,150	115,620	1,476	2,048	120,520
17		500	411.1	25.0	100,000	1,947	3,175	161,700	2,052	2,855	165,000
18		750	540.5	37.5	128,500	2,458	3,940	205,840	2,691	3,715	214,130
19		1,000	660.0	50.0	157,500	2,929	4,755	245,260	3,191	4,445	254,270
20	6	100	144.0	5.0	40,470	929	1,607	75,839	1,040	1,586	78,717
21		200	208.0	10.0	54,500	1,768	2,626	106,975	1,883	2,537	137,680
22		300	302.0	15.0	74,500	1,765	2,874	136,515	1,947	1,974	143,495
23		500	435.0	25.0	100,000	2,477	4,054	186,220	2,731	3,877	196,470
24		750	575.0	37.5	128,500	3,102	5,171	249,990	3,149	4,620	247,980
25		1,000	698.0	50.0	157,500	5,445	8,281	488,760	5,801	7,980	499,570

Table 16-4. Administrative Facilities Construction Requirements

	1	2	3	4	5	6	7	8	9	10
1	Standard	Size of office space (M sq m)	Electric (kw)	Water (gal per day)	With steel-frame buildings			With wood-frame buildings		
					STON	MTON	Man-hours	STON	MTON	Man-hours
2	3	0.93	12.6	250	97	152	6,409	110	142	7,510
3		2.32	28.5	625	229	362	15,275	261	340	18,135
4		4.65	56.5	1,250	443	704	27,850	504	654	33,550
5	4	0.93	12.6	250	115	158	7,120	139	178	8,500
6		2.32	28.5	625	247	387	16,010	289	366	19,150
7		4.65	56.5	1,250	471	740	28,760	543	706	34,700
8	6	0.93	12.6	1,250	126	178	7,960	150	198	9,340
9		2.32	28.5	3,120	272	423	17,290	312	402	20,420
10		4.65	56.5	6,250	509	800	30,810	676	836	36,750

Table 16-5. Data on Installation Areas in Approximate Acreages

1	2	3	4	5	6	7
Typical units	Approximate number of troops	Cantonment area (acres)	Miscellaneous activities area (acres)	Field exercise area (acres)	Firing and impact area (acres)	Total (acres)
2 Inf div	30,000	2,200	1,000	50,000	140,000	193,200
3 Inf div (mech)	30,000	2,200	1,000	70,000	140,000	213,200
4 Armd div	30,000	2,200	1,000	70,000	140,000	213,200
5 Abn div	30,000	2,200	1,000	50,000	90,000	143,200
6 Corps trps	30,000	2,400	1,000	10,000	40,000	53,400
7 ADA firing cen	2,500	250	150	6,000	70,000	76,400
8 Tk firing cen	2,500	250	150	Not required	140,000	140,400

construction requirements for open and covered depots, including ammunition, according to the following standards:

(1) *Standards.* Estimates are based on four standards of construction for covered and open dry cargo storage and three standards for ammunition storage as follows:

(a) *Dry cargo storage.*

1. *Standard 2.* Class IV tents for all facilities requiring cover. Open storage cleared, graded, and drained. Roads graded, but not surfaced.

2. *Standard 3.* Sheds for covered storage; class IV tents with floors for administrative space; without floors for other facilities requiring cover. Roads stabilized. Railroad sidings to open storage areas. Drainage and fencing provided when required.

3. *Standard 4.* Storage on 152 millimeters (6 inches) of crushed stone with asphalt binder. Administration in tents and latrines in buildings.

4. *Standard 5.* Closed buildings for covered storage and administrative facilities. Bitu-

minous-surfaced main access roads to covered and open storage areas; other interior roads stabilized. Railroad sidings to storage areas. Drainage and fencing provided when required. Electricity provided to all buildings.

b. *Ammunition storage.*

1. *Standard 2.* Class IV tents for 10 percent of the ammunition tonnage and for administrative facilities. Open storage areas cleared and graded. Latrines in wood-frame buildings. Access roads graded but not surfaced.

2. *Standard 3.* Sheds for 10 percent of the ammunition tonnage. Buildings for administrative facilities. Access roads and parts of open storage areas stabilized with local materials. Railroad sidings to storage areas.

3. *Standard 5.* Ten percent storage, administrative, check-point, and shop; latrine in buildings.

(2) *Material and man-hour requirements.* Requirements for storage construction of the standards in (1) above are as shown in tables 16-6, 16-7, 16-8, and 16-9.

Table 16-6. Storage, Dry Cargo, Covered-Depot Construction Requirements

1	1	2	3	4	5	6	7	8	9	10
	Standard	Gross space (M sq m)	Electric (kw)	Site area (sq m)	With steel-frame buildings			With wood-frame buildings		
					STON	MTON	Man-hours	STON	MTON	Man-hours
2	3	1.11	-----	4,000	54	107	4,120	97	97	5,220
3	-----	2.32	-----	6,000	106	220	6,055	147	175	7,315
4	-----	4.65	-----	12,000	143	291	9,400	293	370	14,530
5	-----	9.30	-----	21,200	422	878	9,495	539	700	27,490
6	5	1.11	3.1	4,000	108	163	7,200	172	199	8,610
7	-----	2.32	6.7	6,000	204	322	10,920	275	338	12,650
8	-----	4.65	13.3	12,000	338	495	20,010	547	672	26,010
9	-----	9.30	27.2	21,200	800	1,273	23,340	1,021	1,180	37,690

Table 16-7. Storage, Dry Cargo, Open-Depot Construction Requirements

1	1	2	3	4	5
	Standard	Site Size (M sq m)	STON	MTON	Man-hours
2	2	4.65	12	10	3,048
3	-----	9.30	18	16	5,828
4	-----	18.60	34	32	11,018
5	4	4.65	64	86	5,400
6	-----	9.30	122	167	9,420
7	-----	18.60	242	331	17,810

f. *Other Facilities.* Material and man-hour requirements for construction of other facilities are shown in tables 16-10 and 16-11.

16-5. Site Preparation

Tables 16-12 through 16-16 pertain to site preparation.

Table 16-8. Storage, Ammunition (10-Percent Covered: 90-Percent Open)—Depot Construction Requirements

1	2	3	4	4	5	6	7	8	9
1	Standard	Capacity (tons)	Site area (sq m)	With steel-frame buildings			With wood-frame buildings		
				STON	MTON	Man-hours	STON	MTON	Man-hours
2	2*	5,000	184,000	59	48	66,677	59	48	66,677
3	3	15,000	700,000	400	521	221,800	512	559	228,100
4	5	15,000	700,000	1,392	1,772	281,939	1,709	2,044	288,931

* Tentage materials used.

Table 16-9. Storage, Refrigerated—Depot Construction Requirements

	1	2	3	4	5	6	7
1	Facility	Size	Electric (kw)	Water (gal per day)	STON	MTON	Man-hours
2	Warehouse	102 sq m	15.6	100	41	92	1,600
3	Warehouse	186 sq m	23.9	100	76	175	2,400
4	Warehouse	1,635 sq m	141.0	100	552	1,312	13,640
5	Iceplant	1.0-ton	0.1	250	18	30	870
6	Iceplant	3.6-ton	10.0	1,000	23	43	1,120
7	Iceplant	15.0-ton	46.3	4,000	131	243	2,950

Table 16-10. Shop Construction Requirements *

	1	2	3	4	5	6	7	8
1	Size (m)	Capacity (M sq m)	With steel-frame buildings			With wood-frame buildings		
			STON	MTON	Man-Hours	STON	MTON	Man-Hours
2	12.2 by 30.5 -----	0.37	20	34	818	70	96	3,920
3	18.3 by 91.5 -----	1.67	83	152	2,820	236	328	12,600
4	24.0 by 73.2 -----	1.78	91	160	3,041	262	340	14,900
5	36.6 by 73.2 -----	2.68				302	423	16,490
6	42.7 by 97.6 -----	4.16				512	717	30,730

* Figures are for phase I construction.

Table 16-11. Personnel Service Facilities Construction Requirements

	1	2	3	4	5	6	7	8	9	10
1	Facility	Size	Electric (kw)	Water (M gal per day)	With steel-frame buildings			With wood-frame buildings		
					STON	MTON	Man-hours	STON	MTON	Man-hours
2	Drycleaning plant, with boilerhouse.	1,000-man -----	34.5	0.21	-----	-----	-----	81	106	3,620
3	Drycleaning plant, with boilerhouse.	2,500-man -----	46.3	0.26	-----	-----	-----	93	120	4,060
4	Drycleaning plant, with boilerhouse.	5,000-man -----	74.5	0.40	-----	-----	-----	118	148	4,750
5	Laundry, with boilerhouse.	2,500-man -----	35.4	45.00	-----	-----	-----	174	230	6,650
6	Laundry, with boilerhouse.	5,000-man -----	69.0	94.00	-----	-----	-----	251	315	8,620
7	Laundry, with boilerhouse.	10,000-man -----	117.4	166.00	-----	-----	-----	441	534	15,250
8	Base post office, type O, std 3.	1,040-sq m -----	8.2	0.09	86	144	6,270	136	167	8,680
9	Base post office, type P, std 3.	1,490-sq m -----	21.8	0.13	137	224	8,790	168	210	8,680
10	Base post office, type U, std 3.	7,400-sq m -----	49.4	0.52	695	1,161	39,320	816	1,041	38,150
11	Recreation center, std 2 ^a and 3 ^a	5,000-man -----	21.4	10.00	-----	-----	-----	^b 131	^b 171	^b 9,670
12	Recreation center, std 4	5,000-man -----	28.3	10.00	350	538	21,790	495	676	28,120
13	Recreation center, std 5	5,000-man -----	40.3	10.00	492	758	29,400	602	827	38,750
14	Recreation center, std 4	10,000-man -----	52.5	20.00	622	1,005	36,380	867	1,228	48,970
15	Recreation center, std 5	10,000-man -----	79.5	20.00	888	1,323	57,209	1,092	1,441	59,115

^a Tentage material used.^b Figures apply to standard 3 only.

Table 16-12. Site Preparation—Clearing and Grubbing

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Clearing and grubbing by hand:				
Cutting trees and brush	1000 SY	7.0	4.8	2.0
Piling and burning	1000 SY	1.7	1.2	0.5
Digging and blasting stumps	Each	0.3	0.2	0.1
Cutting large trees	Each	0.6	0.4	0.2
Clearing and grubbing with equipment:				
Clearing trees and brush	1000 SY	0.7	0.4	0.2
Rooting out stumps	Each	0.20	0.10	0.05
Loading and hauling	1000 SY	2.8	1.6	0.8
Burning trees and brush	1000 SY	0.7	0.4	0.2
For quick estimates. ¹				
Clearing and grubbing:				
By hand	1000 SY	9.6	6.6	2.8
With equipment	1000 SY	2.20	1.30	0.65

Typical crew: Hand work—1 crew leader, 4 to 8 men with brushhooks and axes, 1 to 2 men with portable chain saws.

Typical crew: With equipment—1 crew leader, 1 bulldozer operator, 2 to 5 men with chain saw and axes cutting and trimming large trees.

Typical crew: Burning—2 to 5 men.

Note: Most stumps can be rooted out with a bulldozer unless the ground is very hard. Brush should not be burned until it has dried for several weeks. Old tires burned with the brush pile help to keep the fire going.

¹ Based on burning brush and trees at site, and 1 large tree per 1000 SY.

Table 16-13. Clearing Rates for Dozers

Types of clearing	Rate
Brush and small trees	1,000 sq yd per hour
Medium trees 4"-10" dia	2-9 min per tree
Large trees over 10" dia	5-20 min per tree

Table 16-14. Site Preparation—Earthmoving, Cut and Fill

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Excavate from borrow pit and load into trucks	1000 CY	11.2	6.9	2.5
Haul with trucks	1000 Yd. Mi.	5.2	3.1	1.4
Excavate, load, and haul (scrapers) ¹	1000 CY	16.0	10.0	3.6
Spread fill, sprinkle and compact fill	1000 CY	12.9	8.0	2.9
Remove concrete slabs and sidewalks	1000 SY	5.4	3.3	1.2
Remove asphaltic concrete	1000 SY	4.5	2.8	1.0
For quick estimates:				
Earthmoving, cut and fill ²	1000 CY	29.0	18.0	6.5

Typical crew: 1 crew leader at pit, 1 end loader and 5 dump trucks loading and hauling; crew leader and dumper at site, 1 dozer spreading, 1 tractor and 1 sheepsfoot tandem roller and 1 water wagon spreading and compacting. Number of trucks for each end loader will vary with length of haul. More than one spread of end loader and trucks may be used to advantage if borrow pit and site are large enough to work additional equipment and work quantity warrants it.

Typical crew: Scraper work—1 crew leader at pit, 2 or more scrapers with 1 or more pusher tractors. Spreading and compacting crew would be the same as noted above for work performed with end loader and dump trucks.

Note. Either method of operation will require a bulldozer part to full time in pit and grader part to full time on haul roads. Embankment should be smoothed at quitting time and preferably rolled to seal against moisture when there is a possibility of rain. Embankment should be sloped so that it will drain at all times during construction.

Scraper operation will normally require less man-hours per cubic yard but is efficient only for short hauls of 4000 feet or less.

¹ Based on haul distance of 4,000 feet or less.

² The man-days per unit shown for this work element are approximately correct for scraper work and hauls with trucks up to one mile. For longer hauls add man-days per unit figure for "haul with trucks" for each additional mile of haul.

Table 16-15. Excavation for Footings and Foundations

Work element description	Unit	Man-days per unit ¹		
		Adverse condition		Favorable condition
Machine excavation for footings and foundations:				
Excavations	1000 CY	50	25	12
Load excess earth	1000 CY	9.0	4.5	2.0
Haul excess earth	1000 Yd M ₁	5.2	3.1	1.4
Spread spoil pile	1000 CY	2.1	1.4	0.7
Spread excess earth	1000 CY	4.5	3.0	1.5
Backfill	1000 CY	9	6	3
Compaction	1000 CY	12	8	4
Hand excavation for footings and foundations:				
Excavation	CY	1.2	0.7	0.3
Load excess earth	CY	0.8	0.4	0.2
Spread excess earth	CY	0.18	0.12	0.06
Backfill	CY	0.35	0.20	0.10
Compaction	CY	0.55	0.35	0.15
For quick estimates and excavating footings and foundations:²				
Machine excavation, complete	1000 CY	72	38	18
Hand excavation, complete	CY	2.1	1.0	0.5

Typical crew: Machine work—1 crew leader, 2 men on excavating equipment 2 to 6 trucks with operators, 1 man on equipment spreading and backfilling, 1 man on compacting equipment.

Typical crew: Hand work—1 crew leader, 2 to 10 men excavating, loading and/or spreading excess dirt, backfilling and tamping.

¹ Includes trimming and fine grading.

² Includes removal and disposal of excess dirt, backfilling, and compaction.

Table 16-16. Trenching, Ditching, and Backfilling

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Machine excavation for trenches and ditches:				
Excavation	1000 CY	80	55	25
Bell holes (hand)	Each	0.03	0.02	0.01
Backfill	1000 CY	10.0	6.0	2.5
Compaction	1000 CY	14	9	4
Hand excavation for trenches and ditches:				
Excavation	CY	1.10	0.55	0.25
Bell holes	Each	0.03	0.02	0.01
Backfill	CY	0.35	0.20	0.10
Compaction	CY	0.55	0.35	0.15
For quick estimates:¹				
Machine trenching and ditching	1000 CY	104	70	32
Hand trenching and ditching	CY	2.0	1.1	0.5

Typical crew: Machine work—1 crew leader, 2 men on excavating equipment, 2 to 4 men trimming and grading, 1 to 2 men digging bell holes, 1 man on backfilling equipment and 1 man on compacting equipment.

Typical crew: Hand work—1 crew leader, 2 to 10 men excavating, 1 to 2 men digging bell holes, 2 to 8 men backfilling and tamping.

¹ Includes backfilling and compaction, but no bell holes.

16-6. Earth Moving

a. Tables 16-17 through 16-23 pertain to earthmoving.

b. *Formulas and Rules of Thumb.*

(1) *Work output of dozers.*

$$\text{Output (in loose cu yd per hour)} = \frac{Q \times 60 \times E}{C}$$

Where: Q = blade capacity in loose cu yd

60 = minutes per hour

E = efficiency

C = cycle time in minutes, consisting of fixed time (table 16-16) and variable time (depends on speed and length of haul)

Note: The approximate soil conversion factor from table 16-19 may be applied to obtain the output in compacted or in-place cubic yards.

Table 16-17. Approximate Fixed Time Constants

	Fixed time constants (minutes)		
	5th gear haul	4th gear haul	3d gear haul
Wheel-tractor drawn scrapers, push loaded:			
Loading	1.0	1.0	1.0
Dumping and turning	0.5	0.5	0.5
Acceleration and deceleration	1.5	0.8	0.4
Total fixed time.	3.0	2.3	1.9
Crawlers-dozers shuttle dozing only	Using same gear speed, shifting only with forward-reverse lever.		Shifting to higher gear when reversing.
Total fixed time (loading and dumping)			
	0.1		0.2
	Self-loading	Push-loading	
Crawler-tractor drawn scrapers:			
Loading	1.5	1.0	
Dumping	1.0	1.0	
Total fixed time.	2.5	2.0	
Pusher dozers:			
Pushing	1.0		
Returning	1.0		
Total cycle time.	2.0		

Table 16-18. Typical Rolling Resistance Factors

Type of haul road	Resistance *
Hard, smooth, stabilized roadway without penetration under load (concrete or black-top).	40
Firm, smooth-rolling roadway, flexing slightly under load (macadam or gravel-topped road).	65
Rutted dirt roadway, flexing considerably under load (hard clay road, 1-to 3-inch tire penetration).	100
Rutted dirt roadway, no stabilization, somewhat soft under travel (4- to 6-inch tire penetration)	150
Soft, muddy, rutted roadway, or sand	200-400

* Values of resistance represent drawbar pull, in pounds per short ton of gross weight, required for crawler tractors to overcome rolling resistance for the haul roads indicated; for wheeled tractors, the values represent rimpull in pounds per short ton of gross weight. Gross weight is the weight of tractor, scraper, and load for wheeled-tractor scraper units; the weight of scraper and load only for crawler, tractor scraper units. In the absence of the above data, or for haul roads which do not fall under one of the above categories, and approximation may be made using this formula: Rolling resistance = 40 lb plus 30 lb for each inch of tire penetration.

Table 16-19. Soil Conversion Factors

Soil type	Initial condition	Converted to—		
		In-place	Loose	Compacted
Sand	In-place	—	1.11	0.95
	Loose	0.90	—	0.86
	Compacted	1.05	1.17	—
Loam	In-place	—	1.25	0.90
	Loose	0.80	—	0.72
	Compacted	1.11	1.39	—
Clay	In-place	—	1.43	0.90
	Loose	0.70	—	0.63
	Compacted	1.11	1.59	—
Rock (blasted)	In-place	—	1.50	1.30
	Loose	0.67	—	0.87
	Compacted	0.77	1.15	—

(2) Work output of scrapers.

$$\text{Output (in loose cu yd per hr)} = \frac{Q \times 60 \times E}{C}$$

Factors are the same as for dozers, but to compute C, allowance must be made for rolling resistance (table 16-17), grade resistance, altitude effects, and traction limitations (table 16-18).

(a) *Grade resistance.* Each 1 percent of adverse (plus) grade requires 20 pounds drawbar pull or rimpull per short ton of gross weight (combined weight of tractor, scraper, and load for both crawler and wheeled tractor-scraper combinations). Each 1 percent favorable (minus) grade decreases the drawbar pull or rimpull required by 20 pounds per short ton of gross weight.

(b) *Altitude effects.* The available drawbar pull or rimpull is reduced 3 percent for each 1,000 feet of elevation, or major fraction thereof, in excess of 3,000 feet above sea level.

(3) Work output of rollers.

$$\text{Cu yd per hour loose} = \frac{60 \times S \times W \times E \times D}{N \times 27}$$

$$\text{Square yd per hour} = \frac{60 \times S \times W \times E}{N \times 9}$$

60 = min per hour

S = speed in feet per minute

W = effective width of roller in feet

16-7. Paving Estimates

Tables 16-24 through 16-26 pertain to paving estimates.

16-8. Building Construction Estimates

Tables 16-27 through 16-35 pertain to building construction estimates.

Table 16-20. General Excavation

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Machine work:				
Excavating (no trim nor handwork) -----	1000 CY	25	12	6
Loading -----	1000 CY	9.0	4.5	2.0
Hauling -----	1000 Yd Mi	5.2	3.1	1.4
Spreading -----	1000 CY	4.5	3.0	1.5
Backfilling -----	1000 CY	9	6	3
Compacting -----	1000 CY	12	8	4
Grading -----	1000 SY	1.6	0.8	0.4
Hand work:				
Excavating -----	CY	1.2	0.7	0.3
Loading -----	CY	0.8	0.4	0.2
Spreading -----	CY	0.18	0.12	0.06
Backfilling -----	CY	0.35	0.20	0.10
Compacting -----	CY	0.55	0.35	0.15
Shoring Walls of excavation -----	1000 SF	40	24	8

Typical crew: Machine work—1 crew leader, 2 men on excavating equipment, 2 to 6 men on hauling equipment, 1 man on spreading and backfilling equipment, 1 man on compact equipment, and 1 man on grading equipment.

Typical crew: Hand work—1 crew leader, 2 to 10 men excavating, loading, spreading backfilling, compacting, trimming and fine grading.

Typical crew: Shoring—2 or more men.

Table 16-21. Earth Fill Structures

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Clear and grub site -----	1000 SY	4.3	1.8	0.4
Excavate and load -----	1000 CY	11.2	6.9	2.5
Hauling -----	1000 Yd Mi	5.2	3.1	1.4
Spreading and compacting -----	1000 CY	18	9	4
Erosion control:				
Grass -----	1000 SY	21	14	7
Riprap (12" thick) -----	1000 SY	22.5	15.0	7.5
For quick estimates:				
Earth fill structure, complete ¹ -----	1000 CY	54	35	15

Typical crews: 1 crew leader, 3 to 5 men plus equipment for clearing and grubbing, 1 man with equipment removing top soil and clearing borrow pit; 1 crew leader and 2 to 5 men with equipment excavating and loading, 5 to 15 men with equipment hauling; 1 crew leader and 3 to 7 men spreading and compacting fill; 1 crew leader and 5 to 10 men installing erosion control plus equipment and men hauling materials.

¹ Includes all clearing, borrowing, hauling, compacting and erosion control.

Table 16-22. Preparing Subbase and Base

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Machine work:				
Excavate and load selected material -----	1000 CY	16.0	9.8	3.6
Haul -----	1000 Yd Mi	5.2	3.1	1.4
Spread, sprinkle and compact -----	1000 CY	44	27	10
Fine grade, sprinkle and compact ¹ -----	1000 SY	6.0	3.5	1.2
Hand work ²:				
Spread, sprinkle and compact -----	CY	0.75	0.50	0.23
Fine grade, sprinkle and compact ¹ -----	SY	0.10	0.07	0.03
For quick estimates (6" compacted base) ³:				
Machine work -----	1000 SY	16	12	4
Hand work ⁴ -----	SY	0.16	0.10	0.05

Typical crew: Machine work—1 crew leader, 2 to 4 men on equipment loading and shaping pit; 2 to 6 men on hauling equipment, 3 to 5 men on equipment spreading, sprinkling, compacting and fine grading.

Typical crew: Hand work—1 crew leader and 2 to 10 men spreading, sprinkling, compacting, and fine grading.

¹ This element applies only to the final grading and compacting of top lift after initial compaction of top lift has been completed.

² These elements to be used in tight quarter and adjacent to buildings where there is not sufficient room for large equipment to operate.

³ Includes loading, hauling, spreading, compacting and fine grading.

⁴ Loading and hauling with equipment, all other work by hand.

Table 16-23. Coefficient of Traction for Tractors*

Material	Wheeled tractors	Crawler tractors	Material	Wheeled tractors	Crawler tractors
Concrete	.90	.45	Packed snow	.20	.25
Clay, dry	.55	.90	Ice	.12	.12
Clay, wet	.45	.70	Firm earth	.55	.90
Clay, rutted	.40	.70	Loose earth	.45	.60
Loose sand	.30	.30			
Quarry pit	.65	.55			
Gravel road (loose, not hard)	.36	.50			

*The usable pounds pull is equal to the coefficient of traction times the weight on the drive wheels for wheeled tractors or the tractor weight for crawler tractors.

Table 16-24. Paving—Curbs and Walks

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Concrete curbs:				
Place and remove forms	1000 SFCS	60	40	20
Place reinforcing	Ton	18	12	6
Place and cure concrete	CY	1.05	0.70	0.35
Finish, when required	1000 SF	24	16	8
Concrete walks:	SFCS			
Place and remove forms	1000 SFCS	51	34	17
Place concrete	CY	0.54	0.36	0.18
Finish concrete	1000 SF	12.0	8.0	4.0
Cure	1000 SF	1.5	1.0	0.5
Asphalt walks:				
Place and remove forms	1000 LF	13.5	9.0	4.5
Apply prime coat	1000 SF	1.2	0.8	0.4
Spread asphalt	1000 SF	7.5	5.0	2.5
Roll asphalt	1000 SF	3	2	1
For quick estimates:				
Concrete curbs (6" x 18"), complete	1000 LF	246	148	70
Concrete walks, complete	1000 SF	28.5	19.0	9.5
Asphalt walks, complete	1000 SF	18	12	6

Typical crew concrete curbs: 1 crew leader, 4 men setting forms, 2 men placing reinforcing, 3 men placing concrete.

Typical crew concrete walks: 1 crew leader, 3 men setting forms, 6 men placing, finishing and curing concrete.

Typical crew asphalt walks: 1 crew leader, 2 men setting forms, 5 men placing and rolling asphaltic concrete.

Note. Base preparation not included. For man-day information on base preparation see table 16-22. For mixing concrete at site see table 16-38.

Table 16-25. Concrete Paving

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Place and remove forms	1000 LF	15	10	5
Place reinforcing mesh and dowel	1000 SY	54	36	18
Place reinforcing steel and dowels	Ton	15	10	5
Mix and place concrete ¹	CY	0.25	0.12	0.06
Place concrete ²	CY	0.60	0.30	0.15
Finish concrete	1000 SY	40	25	12
Place premolded expansion joint	1000 LF	20	10	5
Cut or form longitudinal and transverse joints	1000 LF	21	14	7
Place joint sealer	1000 LF	14	8	4
Curing	1000 SY	15	10	5
For quick estimate:				
Concrete paving, complete	1000 SY	162	94	47

Typical crew: 1 crew leader, 4 to 8 men placing or removing forms, 6 to 12 men placing reinforcing and dowels, 11 men mixing, placing and vibrating and 10 men finishing. 1 crew leader, and 4 men sawing and sealing joints.

¹ Based on using paving mixers.

² Based on using transit mix trucks.

Table 16-26. Asphalt Paving

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Apply prime, tack or seal coat	1000 SY	6.0	2.5	0.7
Spread and finish asphaltic concrete	1000 SY	35.0	12.5	5.0
Roll asphaltic concrete	1000 SY	5.0	2.0	0.7
Apply chip for gravel coat	1000 SY	6.0	3.0	1.0
For quick estimate:				
Asphaltic concrete paving	1000 SY	52.0	18.0	6.5
Single pass surface treatment	1000 SY	18.0	8.0	2.4
Double pass surface treatment	1000 SY	30.0	13.5	4.2

Typical crew for asphaltic concrete: 1 crew leader, 2 men distributing prime, tack or seal coat, 4 to 6 men on asphalt finishing machine, 1 man rolling, 2 to 4 additional men as required.

Typical crew for surface treatment: 1 crew leader, 2 men distributing prime and tack coat, 2 to 3 trucks hauling chips, 1 endloader loading chips from job stockpile, 5 to 9 men spreading chips.

Table 16-27. Heavy Timber Construction
(Approximate Man-Hours to Prepare Timbers)*

Size	Cross cutting	Ripping per lin ft	Chamfering per lin ft	Drilling hole less than 1" dia	Drilling 1"-1.5" dia hole	Notching
4 x 6	.03-.04	.02-.03	.01-.02	.04-.05	.04-.06	.06-.08
4 x 8	.04-.05					
4 x 12	.05-.06					
6 x 6	.04-.05	.04-.05	.03-.04	.05-.06	.06-.07	.08-.1
6 x 8	.05-.06					
6 x 12	.06-.07					
6 x 18	.1 -.12					
8 x 8	.07-.08	.08-.1	.06-.08	.07-.08	.08-.09	.18-.2
8 x 12	.1 -.15					
8 x 18	.16-.18					
8 x 24	.2 -.25					
10 x 10	.15-.18	.2-.25	.1 -.12	.1 -.13	.12-.14	.25-.3
10 x 12	.2 -.25					
10 x 18	.31-.35					
10 x 24	.35-.4					
12 x 12	.25-.3	.3 -.4	.15-.2	.12-.15	.15-.18	.35-.4
12 x 18	.35-.4					
12 x 24	.45-.5					

*Figures are based on use of power tools and preparation of timbers on ground prior to erection. Included is time for handling the timbers. Figures will vary with the extent of repetitive operations and the use of jigs and stops, with distances from storage to working areas, and with experience of crews.

Table 16-28. Heavy Timber Construction
(Approximate Man-Hours to Place and Fasten Timbers)*

Item	Man-hours
Columns	1.5-1.8
Girders	1.6-2.0
Beams	1.1-1.5
Laminated flooring**	7.5-9.0
Plank flooring and roofing**	4.2-5.8

*Figures are based on one-story construction and use of power derricks or cranes. Add hoisting time for additional stories.

**Per 100 square feet of floor or roof area.

*Table 16-29. Light Frame Construction (Approximate
Man-Hours for Cutting and Erection Per 1,000 Feet
Board Measure)**

Item	Man-hours	Item	Man-hours
Sills	25-40	Roof decking:	
Girders	30-45	Unmatched boards	15-25
Joists	25-35	Matched boards	20-30
Bridging	70-90	Plywood	12-18
Studs	25-45	Wall sheathing:	
Plates	25-45	Unmatched boards—	
Rafters	25-40	Straight	15-25
Roof trusses, light	50-60	Diagonal	20-30
Subflooring:		Matched boards—	
Unmatched boards—		Straight	20-30
Straight	15-25	Diagonal	25-35
Diagonal	20-30	Plywood	12-18
Matched boards—			
Straight	20-30		
Diagonal	25-35		
Plywood	12-18		

*Figures are based on use of power tools, and will vary with sizes of lumber, spacing of parts such as rafters and joists, and experience of crews. Figures for plywood are man-hours per 1,000 square feet.

*Table 16-30. Steel Construction (Approximate Man-Hours for Principal Operations)**

Operation	Unit	Man-hours per unit
Steel fabrication:		
Bolting	Bolt	.045
Chipping	Linear foot	.083
Cutting (oxyacetylene torch):		
Long straight cuts	Linear foot	.040
Average cutting	Linear foot	.067
Drilling	Linear inch	.022
Handling (arrival at yard through fabrication)	Ton	7.0
Laying out:		
Scratching	Hole	.040
From templates	Hole	.030
Painting:		
Brush	Square foot	.006
Spray	Square foot	.003
Reaming	Hole	.067
Template making	Hole	.060
Welding (pounds of weld metal deposited)	Pound	.35
Steel erection:		
Bolting	Bolt	.060
Handling (through raising, plumbing and temporary bolting):		
Skeleton frame buildings	Ton	3.5
Warehouse or mill type buildings	Ton	5.0
Girder or stringer bridge spans	Ton	2.5
Bridge trestle towers	Ton	3.5
Painting:		
Brush	Square foot	.024
Spray	Square foot	.010
Reaming	Hole	.067
Welding (pounds of weld metal deposited)	Pound	.70
Timber falsework construction:		
Bolting	Bolt	.133
Boring	Linear inch	.100
Driving driftbolts	Bolt	.017

See notes below table.

Table 16-30. Steel Construction (Approximate Man-Hours for Principal Operations)*—Continued

Operation	Unit	Man-hours per unit
Driving nails	Nail	.003
Driving spikes	Spike	.008
Timber falsework construction:		
Driving piles	Linear foot	.200
Handling:		
Arrival at site through fabrication	MBF	10.0
Piles	Pile	1.0
Span erection	MBF	4.0
Tower erection	MBF	6.0
Laying out	MBF	4.0
Sawing piles	Pile	.167

*Figures are based on skilled workers, operating under good conditions and using power tools. No allowance is made for transport of materials to site, tool and equipment maintenance, supervisory personnel, equipment operators (crane operators, air compressor operators), and unnecessary rehandling of materials and finished members.

Table 16-31. Roofing (Approximate Man-Hours Per Square)*

Item	Man-hours
Roll roofing	.05-2.0
Corrugated sheet metal	0.5-1.5
Roofing paper and felt	0.3-1.0
Shingles, asphalt, 3 and 4 tab	1-4
Shingles, asphalt, single	2-6

*One square of roofing is equal to 100 square feet.

Table 16-32. Plumbing (Approximate Man-Hours for Roughing-In Operations)

Item	Man-hours
Cut, thread and install steel pipe, per joint	
1 in. and smaller	0.6-0.7
1 and 1½ in.	0.8-0.9
1½ and 2 in.	1.3-1.5
2½ and 3 in.	1.8-2.4
4 in.	2.2-2.5
Install copper, tubing, per joint:	
½ and ¾ in.	0.4-0.5
1 and 1½ in.	0.5-0.6
1½ and 2 in.	0.6-0.7
2½ and 3 in.	0.7-0.8
4 in.	0.8-0.9
Install cast-iron soil pipe, per joint:	
2 in.	0.4-0.5
3 in.	0.5-0.6
4 in.	0.7-0.9
6 in.	0.9-1.2
Install vitrified-clay or concrete pipe, per joint:	
4 in.	0.2-0.3

Item	Man-hours
6 in.	0.3-0.4
8 in.	0.5-0.6
10 in.	0.7-0.9
Rough-in for fixtures:	
Bathtub	10-18
with shower	16-24
Drain, floor	5-7
Lavatory	8-14
Shower, stall	12-18
Sink, kitchen, single	8-14
Sink, kitchen, double	10-16
Sink, slop	8-12
Trap, grease	6-10
Tray, laundry, two-compartment	8-12
Urinal, stall	10-14
Urinal, wall hung	8-10
Water closet	12-18

Table 16-33. Plumbing (Approximate Man-Hours for Installing Fixtures)

Fixture	Man-hours
Bathtub	14-20
with shower	18-24
Lavatory	6-8
Sink, kitchen, single	6-10
Sink, kitchen, double	8-12
Sink, slop	6-10
Tray, laundry, two-compartment	10-14
Urinal, stall	16-20
Urinal, wall hung	8-10
Water closet	7-9

Table 16-34. Electric Wiring (Approximate Man-Hours for Principal Operations)

Item	Unit	Man-hours
Service entrance	ea	1.0-2.0
Main switch	ea	0.8-2.0
Fuse box	ea	0.5-1.2
Combined main switch and fuse box	ea	1.0-2.5
Nonmetallic cable with outlet boxes:		
2-conductor, 8-14 ga	100 lin ft	7.0-12.0
3-conductor, 8-14 ga	100 lin ft	8.0-13.0
3-conductor, 4 and 6 ga	100 lin ft	10.0-15.0
Ceiling fixture	ea	0.4-0.8
Wall fixture	ea	0.4-0.8
Wall or floor outlet	ea	0.2-0.4
Wall switch	ea	0.2-0.4
Three-way switch	ea	0.3-0.5
Armored cable with outlet boxes:		
2-conductor, 8-14 ga	100 lin ft	9.0-15.0
3-conductor, 8-14 ga	100 lin ft	10.0-16.0
3-conductor, 4 and 6 ga	100 lin ft	12.0-17.0
Knob and tube wiring with outlet boxes and fixtures:		
2-wire, 10-14 ga	100 lin ft	8.0-11.0
3-wire, 10-14 ga	100 lin ft	10.0-13.0
2-wire, 8 ga and larger	100 lin ft	12.0-14.0
3-wire, 8 ga and larger	100 lin ft	13.0-15.0

Table 16-35. Allowances for Waste

Item	Allowance
Dimension lumber—2" or more thick	10%
Sheathing and flooring—less than 2" thick	20%
Matched board—3" or more wide	33%
Matched boards—less than 3" wide	50%
Other construction material	5%-10%

Table 16-37. Concrete Mixer Production

Item of equipment	Cubic yards per hour
Mixer, concrete, 16 cu ft	10-15
Paver, concrete, dual drum, 34 cu ft	60-75

16-9. Concrete Estimates

Tables 16-36 through 16-38 pertain to concrete estimates.

Table 16-36. Concrete Form Work (Approximate Man-Hours Per 100 Sq Ft of Form Surface)*

Type of form	Cut & assemble	Erect	Strip & clean	Total
Footings and small piers	4-8	3-5	3-5	10-18
Walls	6-10	4-6	3-6	13-22
Floors	4-9	3-5	3-5	10-19
Columns	6-10	4-6	3-5	13-21
Beams and girders	7-11	4-5	3-6	14-22
Stairs	7-13	5-9	4-6	16-28

*Unit of measurement is the actual area of surface of concrete in contact with the form. Figures are based on use of power tools, and will vary with the size and complexity of the forms and with the experience of the crews. Use of plywood sheathing, particularly on large forms, will reduce man-hours by 10 to 20 percent. Repair of stripped and cleaned forms for reuse takes from 3 to 6 hours per 100 square feet for all types of forms.

Table 16-38. Concrete Mixing, Placing, and Curing (Rates Are Per Cubic Yard)

Operation	Man-hours
Mixing:	
By hand	1-2
16 cu ft mixer	.6-.7
Heating water and aggregate	.2-.3
Placing:	
Footings and abutments	1-4
Columns	2-5
Walls	1-4
Doors and slabs	1-4
Curing:	
Warm weather	.5-1
Including protection from freezing	1-5

16-10. Miscellaneous

Tables 16-39 through 16-42 pertain to miscellaneous construction.

Table 16-39. Airfield Construction

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
For preliminary estimates only:				
Concrete runway ¹ -----	SY	0.15	0.10	0.05
Concrete taxiway and hardstand ¹ -----	SY	0.24	0.15	0.07
Control tower -----	Ea	900	600	300
Hangar -----	SF	1.00	0.65	0.40
Runway lighting:				
Direct burial cable -----	1000 LF	41.0	27.0	13.5
Duct system -----	1000 LF	197	122	63
Seaplane washing facilities complete -----	Ea	2700	1800	900

Note. Man-days per unit are for the facility or structure complete.

¹ Includes mixing and hauling of concrete.

Table 16-40. Waterfront Construction

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
For preliminary estimates only:				
Dolphins -----	Pile	5.7	2.6	1.3
Riprap (quarry, haul & place) -----	CY	0.12	0.08	0.04
Timber pier -----	SF	0.15	0.10	0.05
Sheet pile bulkhead including tie back & backfill.	LF	2.1	1.4	0.7

Note. Man-days per unit are for the facility complete.

Table 16-41. Underwater Excavation

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Underwater excavation by dredge:				
Install and remove discharge lines	1000 LF	23	14	9
Build dike around spoil area	1000 CY	3.9	2.4	1.5
Operating dredge	1000 CY	8.3	5.1	3.2
Underwater excavation with clamshell or dragline:				
Excavation	1000 CY	12	7	3
Spoil disposal by truck	1000 CY	23	14	9
Spoil disposal by barge	1000 CY	18	11	7
For quick estimates:				
Dredging	1000 CY	9.6	5.9	3.7
Underwater excavation	1000 CY	30	19	11

Typical crew: 1 crew leader, 4 to 7 men installing and removing discharge lines, 3 to 5 men per shift operating dredge (usually operated on a 2- or 3-shift basis around the clock), 1 man with equipment building dike with 3 men installing drain pipes through dike. For dragline excavation 1 operator and signalman on dragline, 2 to 5 trucks with operators hauling spoil, 1 man to direct loading of spoil on barge, two barges (1 loading and 1 unloading), 2 men and 1 bulldozer unloading barge at disposal area, 1 tugboat and crew (usually 3 to 5 men).

Table 16-42. Erosion Control

Work element description	Unit	Man-days per unit		
		Adverse condition	Average condition	Favorable condition
Machine work:				
Sloping shoulders, banks, and ditches ----	1000 SY	4.0	2.6	1.3
Hauling riprap or rubble -----	1000 Yd. Mi.	5.2	3.1	1.4
Placing riprap or rubble (12" thick) ----	1000 CY	18	12	6
Hand work:				
Sloping shoulders, banks, and ditches ----	1000 SY	33	22	11
Placing riprap or rubble -----	SY	0.09	0.06	0.03
Planting grass sprigs and roots -----	1000 SY	15	10	5
For quick estimates:				
Erosion control—grass -----	1000 SY	21	14	7
Erosion control—riprap (12" thick) ----	1000 SY	22.5	15.0	7.5

Typical crew: Sloping shoulders, banks, and ditches—1 to 2 men on equipment, or 1 crew leader and 3 to 8 men with handtools.

Typical crew: Grass—1 crew leader, 6 to 20 men plowing, harrowing, fertilizing, digging sprigs, hauling sprigs, scattering sprigs, disking, seeding and watering.

Typical crew: Riprap—1 crew leader, and 6 to 20 men hauling and placing riprap.

CHAPTER 17

SURVEYING, MAPS, AND AERIAL PHOTOGRAPHY

Section I. SURVEYING

17-1. General

The military engineer surveyor conducts field surveys in support of construction and mapping projects and to furnish both initial and sustained survey support to the field artillery and air defense artillery units as required. AR 117-5 governs and outlines the responsibilities and functions of all engineer units within the mapping and geodesy fields. Principles and general types of surveying are discussed in FM 6-2, TM 5-233, TM 5-237, TM 5-441, TM 5-442 and TM 5-443.

17-2. Classification

Military surveys are classified into the following four general types:

a. Construction Surveys. These surveys are conducted to obtain data essential to planning and cost estimating of a proposed project, and to establish control points, lines, and grades for construction operations; see TM 5-233. These surveys normally cover areas considered small enough to use plane surveying techniques (para 17-4).

b. Artillery Surveys.

(1) Field artillery fire-control surveys are made to determine relative positions of weapons and targets, and from these the correct firing data may be determined. Although relatively large areas and long distances are often involved, the required accuracy for these surveys does not usually warrant the geodetic survey (para 17-3) procedures. Detailed information of the survey-data requirements can be found in FM 6-2.

(2) Air defense artillery surveys are usually accomplished by geodetic survey procedures. The guided missiles that are presently being employed by the air defense units require a high accuracy survey in which the size and shape of the earth must be taken into consideration. The survey requirements will depend upon the type of missile

employed and are usually outlined in special project instructions.

c. Mapping Surveys. In modern methods of mapping, most of the data are obtained from aerial photographs, but surveys in the field are necessary to coordinate and correlate aerial photograph data with the ground data. The ground data consist of a system of photo identifiable control stations whose geodetic positions are determined. These positions must then be identified on the aerial photographs. Since the control stations are usually distributed over comparatively large areas, their relative positions are determined by topographic or geodetic survey procedures as described in TM 5-441.

d. Special Surveys. These surveys are conducted either with special equipment or for a special purpose. Short range and long range navigation surveys require special equipment and specially trained teams of personnel to operate the equipment. Special equipment surveys are of limited or special interest and texts for use in these surveys are available in the form of contractor's manuals and commercial publications. Underground surveys for mining and tunneling, and hydrographic surveys to determine water depth and to mark obstructions to shipping are special purpose surveys. This group is described in detail in TM 5-235.

17-3. Geodetic Surveys

The mathematical shape of the earth is a spheroid with a major diameter at the equator of about 12,756 kilometers. Distances or areas measured on the surface of the earth are, therefore, not along straight lines or planes but on a curved surface. Geodetic surveys which normally extend over long distances and cover large areas consider this fact and make allowances for it in the computations. To accomplish this, the earth's major and minor diameters are computed accurately, and from these, a spheroid of reference. The

position of each geodetic station is related to this spheroid. The positions are expressed as *latitudes* and *longitudes*, or as *northings* and *eastings* on a rectangular grid system which is correlated with the latitude and longitude (TM 5-241-1). In addition, the plumb line deflection, and its effect on relative positions of the stations is considered in precise work. Geodetic surveys are usually conducted by the military surveyors in support of mapping, artillery, and air defense artillery surveys. Methods, equipment, and computations used in geodetic surveys are described in TM 5-237, TM 5-441 and TM 5-442.

17-4. Plane Surveys

When the extent of the survey becomes small (less than 250 sq km in area) and when only limited accuracy is required, the effect of curvature can be ignored. These surveys are treated as if the measurements were made on a plane and are known as plane surveys.

a. Highway and railroad surveys, which may extend for hundreds of kilometers (miles), are usually in a narrow strip and are considered plane surveys. However, a limited computation of earth's curvature is necessary in this case. On a long traverse survey, an astronomic azimuth is determined at intervals of several kilometers. The astronomic azimuth establishes an astronomic north-south line and may be used to obtain the direction of a survey line. The azimuth values on the lines between astronomic azimuth stations consider the convergence of the meridians.

b. The methods, operations, and measurements in either type of survey are similar, but since the distances between stations and area coverage are usually much greater in geodetic surveying, more precise equipment and procedures are used.

17-5. Survey Networks

a. When mapping, construction, or artillery operations require control positions over large areas, networks of survey control are established. The stations are selected so that they are inter-visible and at comparatively long distances apart. Using precise distance and/or precise angle measurements, the relative positions of these stations are computed. These survey networks are subdivided by spacing stations at closer intervals into a supplementary network for a particular project.

b. If closer spacing or different placement of stations is required, a third-order (para 17-9)

control network can be established by geodetic survey procedures. The positions are computed and referenced to either a rectangular grid (TM 5-241-1) or geodetic system.

c. Surveys tied to network control stations and computed on a universal grid system become part of the network. Stations of these surveys can be used as future control stations at the degree of accuracy of the survey.

17-6. Operations

Surveying consists of making and recording measurements and converting them into usable form. The operations are as follows:

a. Distances and angles are measured to—

(1) Establish points and lines of reference for locating details such as boundary lines, roads, buildings, fences, rivers, bridges, and other existing features.

(2) Stake out or locate roads, buildings, landing strips, and other construction projects.

(3) Establish lines parallel or at right angles to other lines, measure inaccessible distances across rivers, extend straight lines beyond obstacles such as buildings, and do any other work which may require use of geometric or trigonometric principles.

b. Differences in elevations are measured and elevations determined to—

(1) Establish elevation reference points, called bench marks.

(2) Determine elevations of terrain along a selected line for plotting profiles and computing grade lines.

(3) Stake out grades, cuts, and fills for construction projects.

c. Topographic surveys are required to describe or depict the configuration of the surface of the earth, including its relief and position (horizontal and/or vertical) of its natural and manmade features.

d. Field notes are recorded to provide a permanent record of the field work.

e. Office computing converts distance, angle, and rod readings into a more usable form. The measurements may end up as a computed volume of dirt to be moved for a highway cut or fill, an area of land needed for a construction project, or an adjusted position of some point or mark from which other measurements can be made.

17-7. Topographic Units

a. Topographic units in the United States Army that perform topographic surveys in the field are—

(1) Headquarters and Headquarters Company, Engineer Topographic Battalion, Army TOE 5-306.

(2) Engineer Base Survey Company, TOE 5-248.

(3) Engineer Topographic Company, Corps, TOE 5-327.

(4) Team IA Topographic Planning and Control, TOE 5-540.

(5) Team IB Geodetic Survey, TOE 5-540.

(6) Team IC Survey, TOE 5-540.

(7) Team ID Survey (Airborne), TOE 5-540.

b. The smallest topographic survey element to consider in planning field surveys is the survey section. The typical topographic survey section common in all topographic units can usually form three instrument teams. These teams consist of one WO and 11 to 16 EM in the following MOS:

Survey Technician 821A

Section Chief 82D40

Chief, Topo Computer 82E40

Topo Computers 82E20

Topo Surveyors 82D20

Topo Survey Recorders 82D20

Rodmen Tapemen 82A10

Topo Instrument Repairman 41B20

c. The number of survey sections in topographic units at full strength are listed below. With the exception of teams, a platoon headquarters supports the sections.

Hqtrs & Hqtrs Company,		
Engineer Topo Bn,		
Army	1 Platoon	4 Sections
Engineer Base		
Survey Co.	3 Platoons	9 Sections
Engineer Topo Co.		
Corps	1 Platoon	3 Sections
*Geodetic Survey Team IB		1 Section
*Topographic Survey Team IC		1 Section
*Topographic Survey Team		
(Airborne) ID		1 Section

*Designed to increase the productive capacity of fixed strength units where less than company size is needed.

17-8. Accuracy Requirements for Surveys

a. General accuracy requirements for surveys are as shown in table 17-1. For detailed requirements see appendix C, TM 5-441.

b. First order surveys can be accomplished by base survey companies but requires special consideration in planning for its execution.

c. Second order surveys can be accomplished by all topographic units. It is principally used to provide area networks and supplemental cross arcs to first order surveys.

d. Third order surveys can be accomplished by all topographic units and is the basic order most commonly used. In countries where the principal geodetic surveys have been accomplished, third order procedures are used to expand and extend the basic control from which mapping control is established. It is also the order at which surveys are expanded to provide basic control for the extension of conventional artillery survey control.

e. Fourth order surveys include all surveys below accuracy of third order. In the fourth order survey, the ratio of permissible error is dependent upon the mission requirement(s).

17-9. Third Order Surveys

Some factors to be considered and assumptions to be made when planning and executing a third order survey are—

a. *Types of terrain* to be considered are—

(1) Type A: Terrain as typified by the Great Plains of the United States; e.g., relatively flat, sparsely wooded areas.

(2) Type B: Terrain as typified by middle and western Virginia; e.g., rolling hills, moderately wooded with trees to heights of 60 feet.

(3) Type C: Terrain as typified by New Guinea or the Isthmus of Panama; e.g., coastal plains and high, rugged mountains largely covered by jungle with trees varying in height from 20 to 120 feet.

b. *Climate and weather* is that season most conducive to survey operations encountered in the geographic area.

c. *Survey control density* of first and second order accuracy meets the minimum density requirements for extension of third order control.

Table 17-1. Accuracy Requirements for Surveys

Triangulation	First order			Second order		Third order
	Class I	Class II	Class III	Class I	Class II	
Principal uses -----	Urban surveys and scien- tific studies.	Basic network	All other ----	Area networks and supple- mental cross arcs.	Coastal areas, inland waterways, and engi- neering sur- veys.	Topographic mapping.
Probable error in astro- nomic azimuth not to ex- ceed.	0.3" -----	0.3" -----	0.3" -----	0.3" -----	0.5" -----	2.0"
Closure in length (after side and angle condi- tions have been satis- fied) not to exceed.	1 in 100,000 -	1 in 50,000 --	1 in 25,000 ---	1 in 20,000 --	1 in 10,000 ---	1 in 5,000
Traverse						
	First order		Second order		Third order	Fourth order
Probable error in astronomic azimuth not to exceed -----	0.5" -----		2.0" -----		5.0" -----	Depends on mapping re- quirement. Do.
Distance error not to exceed -----	1 in 35,000 -----		1 in 15,000 -----		1 in 7,500 -----	
Closing error after azimuth not to ex- ceed for distance of: 0-16,000 meters ----- 16,000 meters and greater -----	1 in 25,000 ----- .158m√K		1 in 10,000 ----- .300m√K		1 in 5,000 ----- .600m√K	
Leveling						
Closure error not to exceed:						Depends on mapping re- quirement.
in feet -----	0.017√M		0.035√M		0.05√M	
in meters -----	.003√K		0.0084√K		.012√K	

M=miles
K=kilometers

Expansion of first and second order surveys is considered as "special mission" and not a delaying factor in establishing third order survey control.

d. Personnel Proficiency.

e. Reconnaissance and planning of the surveys to be executed are accomplished by topographic technicians and supervisors in direct liaison with the accomplishing survey sections. Trig lists, existing maps, aerial photographs, and operational overlays are provided to the survey sections in a time frame to permit an orderly execution of the survey.

f. Field computations made by the survey section computers are to provide only unadjusted "proof of closure" data to a higher echelon of operational control.

g. Monumenting of survey control is included as a duty of the executing survey section.

h. The equipment is of modern design, specifically:

(1) Angle measuring instruments equal to or exceed requirements as set forth in MIL-T-14132 or MIL-T-52035.

(2) Electronic distance measuring instruments are miniaturized, portable, and of reciprocal function.

(3) Survey towers are lightweight, air-transportable by conventional helicopter, modular in design to permit termination with an instrument stand and observers platform at any section, to exceed 30 meters in height when fully erected, and erection time to maximum height within 8 hours without special preparation.

i. Maintenance support is the repair or replacement of inoperable equipment and is not a retarding factor.

j. Rotary wing aircraft are available when required. Typical progress rates are estimated on this assumption.

k. Advanced survey techniques such as the "ABC System" and "Raydist" are not to be in-

cluded as conventional methods of extending third order survey control in these estimates.

1. *Tables 17-2, 17-3, 17-4, and those condi-*

tions listed above are only a guide and each unit must be considered separately when assigning production deadlines.

Table 17-2. Typical Rates of Progress for Third Order Surveys Utilizing the Survey Section

Method of survey	Basic figure	Av. dist. per set-up or figure			Daily progress (10 hr day)			Monthly progress			Percent rerun		
(1) Triangulation	Quad Triangle	Terrain			Terrain			Terrain			Terrain		
		A	B	C*	A	B	C*	A	B	C*	A	B	C
(7) Traverse (2) Microwave (1) (EDME)	Linear	Kilometers			Figures			Figures					
		9	9	15	3	3	1.5	40	40	15	5	5	5
		6	6	10	7	7	3	100	100	30	5	5	5
(6) (3) Leveling, differential (3 wire, looped)	Linear	Kilometers			Kilometers			Kilometers					
		2	2	0.5 to 2	24	24	4.5 to 9	480	480	120	5	5	5
(4) Astronomic azimuth	Station	Meters			Kilometers			Kilometers					
		250	150	100	6	4.5	2	120	90	45	10	10	15
4) Base line measurement microwave	Base	Every 10 figures of triangulation.			1 hr per base								
(5) (8) Modular tower erection	Tower				6 hr erection per tower								

*In dense jungle areas clearing parties of large size are required.

(1) Includes movement between stations—Vehicle or helicopter.

(2) In planning microwave traversing it must be realized that much depends on the transportation provided for moving equipment. Helicopter supported, and with 10,000 meter observations, a rate of progress in excess of 100 kilometers per day is possible.

(3) Requires 1/2 survey section, foot travel.

(4) Requires 1/3 survey section, travel time not included.

(5) Requires 1/2 survey section, travel time not included.

(6) For single run levels double the daily progress.

(7) Three EDME available per section.

(8) Number of towers required by triangulation or traverse is unpredictable without prior reconnaissance.

Table 17-3. Typical Rates for Computations of Third Order Surveys*

Type of computations	Time factor hours	
	Unadjusted	Adjusted
Triangulation: Quad		
Triangle computations, 24 stations	24	41
Position computations, 24 stations	24	43
Net adjustment, 24 stations	---	120
Trigonometric elevations, 24 stations	84	
Reduction to center, side equation test and statistics on computations of above	10	
Traverse, microwave: 30-40 km in length with 24 stations	---	38
Least square adjustment		80
Leveling, 100 km	9	
Astronomic azimuth—One station		
Circumpolar star	4	
East-west stars	8	

*2 topographic computers are employed in the above rates to provide a check against errors. Standard calculators, tables and DA Forms are used.

Table 17-4. Surveying Instruments

Operation	Instrument	TM reference	Accuracy	Uses	Remarks
Leveling	Locator Hand Level	5-232	4th order	Cross-sectioning and reconnaissance.	
	Abney Hand Level			Slope measurements and reconnaissance.	Has graduated arc to enable % of slope and vertical angle measurements.
	Engineer Level	5-232 5-6300-2		Visual leveling operations and observations, construction and topographic survey.	Known as dumpy type
	Military Level	5-232 5-6675-230-15	3d order		Tilt-leveling type
	Precise Level	5-232 5-441	2d order	Topographic and geodetic surveying.	Wild N-3 type or equivalent.
Direction and Angle Measuring	Engineer Transit 1-minute	5-232 5-6600-3	4th order	Construction surveying	
	Engineer Transit 20-second.	5-232			
	Theodolite 1-minute	5-232 5-6675-232-15			Also is available in two-tenth mil for use in artillery surveying.
	Theodolite 1-second	5-232 5-6675-213-15	2d order		Also is available in .002 mil for use in artillery surveying.
	Theodolite Two-tenth second.	5-232 5-6675-231-15	1st order	Topographic and geodetic surveying.	
	Theodolite One-tenth second.	5-232 5-6675-210-15			Normally used for Astronomic Position.
	Gyro-Azimuth	5-232 5-6675-207-15	4th order	Used to establish true azimuth references.	Used in conjunction with 0.002 mil theodolite by the artillery.

See notes below table.

Table 17-4. Surveying Instruments—Continued.

Operation	Instrument	TM reference	Accuracy	Uses	Remarks
Distance Measuring	Metallic Tape	5-232	4th order	Cross-sectioning and reconnaissance.	Made of woven cotton or linen threads and fine metal wires.
	Steel Tape	5-232	2d order	Construction and topographic surveying.	Graduated in metric and English systems.
	Low Coefficient Tape	5-232	1st order	Topographic and geodetic surveying.	Must be handled as a precise instrument.
	Microwave Devices	5-232 5-6675-227-15			Measures distance by precise timing of modulated radio waves.
	Light Wave Devices	5-232 5-6675-206-15			Measures distance by precise timing of modulated light waves.
Miscellaneous	Planetable and Alidade	5-232 5-6300-1	3d order	Used to produce completed sketch or map in the field.	A stadia or Philadelphia rod must be used in conjunction with the planetable and alidade.
	Altimeter	5-232 5-6675-203-5	4th order	Used in certain leveling operations.	This is an aneroid-type barometer and is also used to provide barometric and elevation readings in conjunction with electronic distance measuring devices.
	Compass	5-232	4th order	Used to check azimuth or bearings in surveying operations.	Usually comes with or attached to direction and angle measuring devices.

1. This table includes those basic instruments used in surveying operations. Additional surveying equipment is needed for all surveying operations. Many of these are discussed in TM 5-232.

2. The Army uses various brand-name instruments and many instruments come in different models, sizes, etc. This table references typical instruments used by the Army and other brand and model references are listed in appendix I, TM 5-232.

3. The column showing the order of accuracy obtainable by the various instruments is order usually done in Army survey operations. Some of the instruments can be used to obtain higher accuracy levels. Only four orders of accuracy are listed as these are the orders used by the Army engineers. Horizontal accuracies below 1 in 5000 are classified as fourth order.

4. The column showing the use of the instruments is the typical engineer uses. Many of these instruments are used by the artillery and for operations other than those listed.

Section II. MAPPING

17-10. Intelligence—Mapping and Aerial Photography

a. Intelligence. The mission of the military intelligence organization is to provide intelligence specialist support to major commanders from division to theater army levels to assist in gathering, analyzing, and producing of intelligence materials. For detailed data concerning organizational concept and intelligence planning, see FM

30-9 and FM 30-9A, FM 101-10-3, and TOE 30-25.

b. Mapping and Aerial Photography. Maps and aerial photography are intelligence items. The following sections in this chapter provide basic data on responsibilities and factors for the estimation of various logistic needs in connection with these items. This information is for general planning only. The specific problem of providing

mapping support for an operation should be coordinated with the engineer of the planning echelon.

c. Functions and Responsibilities. Functions and responsibilities with respect to mapping and aerial photography are given in AR 117-5.

17-11. Types and Scales of Military Maps

a. Types.

(1) *Planimetric map.* A map that represents only the horizontal positions for features represented; distinguished from a topographic map by omission of relief in measurable form.

(2) *Topographic map.* A map that presents relief or the vertical positions of features in measurable form, as well as their horizontal positions.

(3) *Plastic relief map.* A topographic map printed on plastic and molded into three-dimensional form.

(4) *Photomap.* A reproduction of a photograph or photomosaic upon which gridlines, marginal data, place names, and boundaries are added and which, in some instances, depicts relief graphically.

(5) *Plastic relief photomap.* A photomap printed on plastic and molded into three-dimensional form.

(6) *Military city map.* A large-scale topographic map (usually 1:12,500) of a town or city.

(7) *Special maps.* Maps designed for a special purpose, such as trafficability maps, transportation maps, boundary maps, etc.

(8) *Terrain model.* A three-dimensional representation of a portion of the earth's surface, modeled in plaster, sponge rubber, or other materials. Cultural and terrain features may be shown in realistic model form or by map symbol, or they may be omitted entirely.

(9) *Photomosaic.* Assembly of aerial photographs to form a composite picture.

(10) *Joint operations graphics (JOG).* A series of 1:250,000 scale military maps designed for joint ground and air operations. The maps are published in both a ground (JOG-G) and an air (JOG-A) edition. The topographic information is identical on both the ground and air version of the same map sheet. The ground series shows the same elevations and contours in meters while the air series shows the same elevations and contours in feet. Both series emphasize the air landing facilities but the air series has additional

symbols to identify aids and obstructions to air navigation (app C, FM 21-26).

(11) *Pictomap.* PICTOMAP is the acronym for Photographic Image Conversion by Tonal Masking Procedures. It is a map on which the photographic imagery of a standard photomap has been converted into interpretable colors and symbols.

b. Scales.

(1) *Small-scale military maps* are available in scales of 1:40,000,000; 1:10,000,000; 1:5,000,000; and 1:1,000,000. Small scale maps are needed for general planning and for strategic studies by commanders of large units.

(2) *Medium-scale military maps* are available in scales of 1:500,000, and 1:250,000. These maps are required for planning operations, including movements and concentrations of troops and supplies.

(3) *Large-scale military maps* are available at a scale of 1:50,000 and larger. These are intended to meet the tactical, technical, and administrative needs of field units.

c. Map Measurements. Table 17-5 lists map measurements in relation to ground measurements for various scale maps.

17-12. Map Standards of Accuracy

a. Military maps are normally prepared in accordance with National Map Accuracy Standards when proper control density and acceptable map photography are available. A note indicating this is included in the credit note. When source materials or other factors do not permit the meeting of these standards, maps of less accuracy requirements refer to AR 117-5, FM 101-10-1 or FM 21-26.

17-13. Requirements for Maps

a. Copies for Initial Issue.

(1) *General.* Small- and medium-scale maps (other than roadmaps) and aeronautical charts are issued in small quantities to headquarters only. The basis of issue is the unit headquarters, and quantities vary in proportion to the size and mission of the unit.

(2) *Large-scale maps.*

(a) *General.* Basis used in computing allowances of large-scale maps vary with the type and mission of the unit. The company is the basic unit for computing large-scale map requirements. Headquarters and service companies use the same basis as other companies.

Table 17-5. Map Measurements

a. *Equivalent Units of Angular Measure.*

1 mil = 1/6400 circle = 0.05625° = 0.0625 grad

1 grad = 1/400 circle = 16.0 mils = 0°54' = 0.9°

1 degree = 1/360 circle = approx. 17.8 mils = approx. 1.1 grad

b. *Ground Distance at Map Scale.*

Map distance	Ground distance	Representative fraction (RF)					
		1/	1/	1/	1/	1/	1/
		25,000	50,000	100,000	250,000	500,000	1,000,000
One inch	Inches	25,000	50,000	100,000	250,000	500,000	1,000,000
	Feet	2,083	4,167	8,333	20,833	41,667	83,333
	Yards	694	1,389	2,778	6,944	13,888	27,776
	Kilometers	.635	1.27	2.54	6.35	12.7	25.4
	Miles	.393	.790	1.58	3.94	7.9	15.76
	Meters	635	1,270	2,540	6,350	12,700	25,400
One centimeter	Inches	9,843	19,685	39,370	98,425	196,850	393,700
	Feet	820	1,640	3,281	8,202	16,404	32,808
	Yards	273	547	1,094	2,734	5,468	10,936
	Kilometers	.250	.500	1.0	2.5	5.0	10.0
	Miles	.154	.31	.62	1.55	3.1	6.2
	Meters	250	500	1,000	2,500	5,000	10,000

c. *Ground Coverage on Various Scale Maps.¹*

Map format	Scale	Miles N-S	Miles E-W	Square miles	1 inch = approx (mi)	Kilo-meters N-S	Kilo-meters E-W	Square kilo-meters
4°N-S x 6°E-W	1:1,000,000	276	319	88,000	16	444	513	227,832
1°N-S x 2°E-W	1:250,000	69	105	7,200	4	111	169	18,640
30' x 30'	1:100,000	35	27	945	1.6	56.3	43.4	2,446
15' x 15'	1:50,000	17.3	13.3	230	0.8	27.8	21.4	595
7'30" x 7'30"	1:25,000	8.6	6.6	57	0.4	13.8	10.6	146

¹ Figures are given for approximately 40° Latitude.(b) *Infantry and combat engineer units.*

Allowances for infantry and combat engineer units are on the basis of two copies per platoon.

(c) *Armored and infantry (mechanized units).* Allowances for armored and infantry (mechanized) units are computed on the same basis as infantry units plus an additional allowance of one per tank and carriage and two per armored personnel carrier with armament.

(d) *Artillery units.* Allowances for headquarters and service batteries are the same as for infantry units. Allowances for firing batteries are on the basis of one per section plus two per forward observer and liaison officer.

(e) *Airborne units.* Allowances for airborne units are the same as for equivalent ground troops.

(f) *Other units.* Map requirements for other units are on the basis of one per officer and one per reconnaissance noncommissioned officer.

(3) *Roadmaps.* Roadmaps are issued one per vehicle and in limited quantities to unit headquarters.

(4) *Aeronautical charts.* In addition to the headquarters allowances, aeronautical charts are

issued on a basis of two per organic Army aircraft.

(5) *Photomaps.* Photomaps are issued as substitutes for large-scale maps when the latter are not available. When necessary as supplements to topographic maps, photomaps are issued in quantities not exceeding those authorized for topographic maps.

(6) *Hydrographic charts.* Hydrographic charts are issued to units and headquarters as required by the situation and the mission of the unit.

(7) *Headquarters.* In addition to the guides stated above, the quantities shown in table 17-6 are the number of copies of each sheet needed by unit headquarters.

(8) *Summary of totals.* Table 17-7 gives the number of copies of each different sheet for initial issue for average operations and includes a small reserve to be held under unit control.

b. *Replenishment Requirements.* The following percentages refer to quantities a field army requires under its control (in addition to the initial issue) in field army map depots:

Small scale—100% of initial requirements.

Medium scale—100% of initial requirements.

Large scale—50% of initial requirements.

Table 17-6. Headquarters Map Allowances

	1	2	3	4	5	6
1	Unit	Small-scale maps	Medium-scale maps	Large-scale maps	Road maps	Aeronautical charts ¹
2	Field army HQ.	25	75	50	75	50
3	Corps HQ -----	15	40	75	50	25
4	Div HQ -----	5	25	55	50	10
5	Bde HQ -----	1	7	² 14	15	3
6	Bn HQ -----	0	3	² 12	5	0
7	Co HQ -----	0	1	(⁴)	1	0

¹ Add one per organic aircraft.² Bde and bn needs for service units are 50 percent of those for combat units.³ 50 percent of the needs for combat co in paragraph 17-13a(2) per co, whose needs are based on officer strength.

Table 17-7. Summary of Map Totals

	1	2	3	4	5	6
1	Unit	Small-scale maps ¹	Medium-scale maps ¹	Large-scale maps ¹	Road maps	Aeronautical charts ²
2	Fld army Hq and all fld army nondivisional troops.	50	600	1,500	4,500	200
3	Corps HQ and all corps nondivisional troops.	40	600	1,500	3,000	100
4	Inf div -----	25	250	1,190	2,750	150
5	In div (mech).	8	200	1,650	3,650	150
6	Armd div -----	8	200	1,650	3,650	150
7	Abn div -----	8	150	³ 1,000	2,100	140

¹ Number of plastic relief maps not included.² Production and distribution are Air Force responsibilities.

Normally, Air Force distribution to troops is in bulk to CONUS and theater army support command map depots; and the engineer makes detailed distribution.

³ Is 1,500 for airborne operations.

c. Overall Planning Factors.

Initial issue—

Field army 2,700,000 copies ----- 135 tons

Corps 420,000 copies ----- 21 tons

Replenishment—

Field army 180,000 copies/day.. 9 tons/day

17-14. Production of Maps

a. General Production Factors.

(1) In planning an operation, map requirements are estimated well in advance of the operation. Requirements in excess of the production

capability of theater topographic units are requisitioned from CONUS. As a general rule, maps at scales 1:100,000 and larger are reproduced by field army and corps topographic units; maps at scales smaller than 1:100,000 by base topographic battalions assigned to theater army.

(2) Press size ----- 22½ x 30 inches, and 35 x 45 inches.

(3) Impressions 30,000 in a 24-hour work day (Bulk work with press runs of over 10,000 copies per map sheet only).

(4) Average map paper consumption per field army ----- 5,000 reams/month 167 reams/day.

(5) Maximum map paper consumption per field army ----- 500 reams/day

(6) Photomap paper consumption per field army - 1,000 reams/month.

(7) Number of colors or press impressions—
Maximum ----- 8
Standard ----- 5 (black, brown, blue, green, and red).

Expedient ----- 1, 2, 3.

Two- and three-color maps are far superior in readability to one color and should be adopted when time for standard color reproduction is not available.

b. Production Capacity Required.

(1) Field army—3,000,000 impressions per month.

(2) Theater army.

(a) Five million impressions per month for each three field armies supported.

(b) A new mapping capacity of 256 square kilometers per day.

17-15. Storage of Maps

Table 17-8 shows storage requirements for map paper and storage requirements for bundled or crated maps.

Table 17-8. Storage of Maps

a. Map Paper—Storage.

1	2	3
Sheet size (in.)	Line map—high wet strength ¹ (lb per 1,000 sheets)	Photomap-coated two sides lb per 1,000 sheets)
22½ x 29 -----	85.7	98.4
22 x 29 -----	81.9	94.1
24 x 34 -----	104.7	120.4
26 x 32 -----	106.8	122.7
28 x 50 -----	179.6	206.5
35 x 45 -----	201.6	233.1
Thickness, 1,000 sheets.	4 in.	3.5 in.

¹ For U.S. hydrographic charts, use twice the weight shown.

b. Crated or Bundled Maps—Storage.

1	2	3
Item	Avg wt (lb)	Avg cu ft
Bundle, 500 map sheets --	60	2
Crate, 1,000 map sheets --	150	5

17-16. Map Distribution Channels

Distribution of maps through command channels and flow of map requisitions and shipments are shown in figure 17-1.

17-17. Foreign Maps

a. *Use by United States Military Forces.* Foreign maps are seldom issued in an unaltered form to United States military forces. Every effort will be made to transform the style of the foreign map to a style familiar to our forces. This means retaining the basic topographic information within the neatlines of the map, adding conventional marginal data explaining the unfamiliar signs and symbols, and superimposing a military grid. When United States forces are allied with the forces of another nation in a common effort

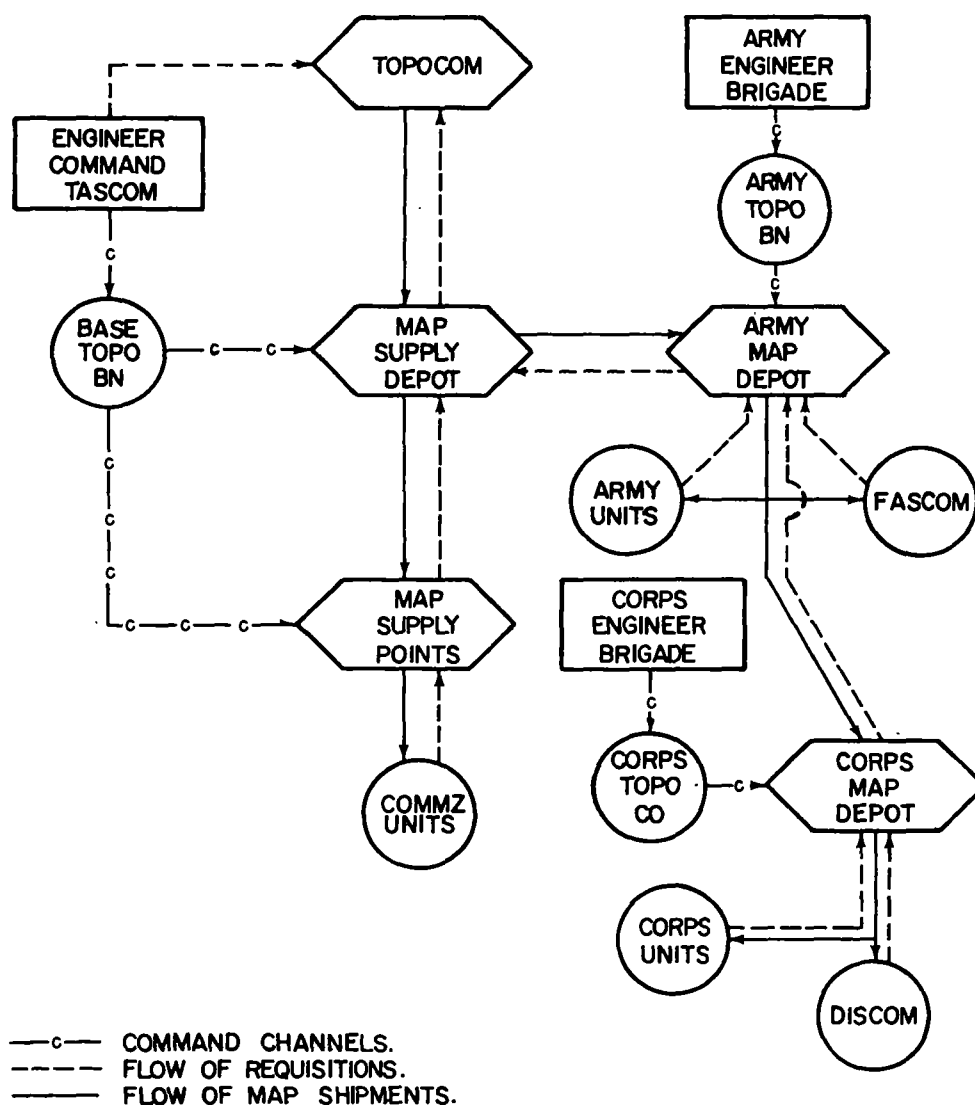


Figure 17-1. Normal map distribution flow chart.

and are committed to use maps compiled in terms of a foreign language and foreign symbols, it is advisable to reprint the maps with bilingual legends and symbol keys. When troops of several allied armies are integrated under a single command, the systematizing of marginal data is a command decision with due regard for the capabilities of the various topographic units involved. In order to convert a foreign map into a military map acceptable by United States Army standards, it is necessary for the topographic unit to have the necessary formulas for making grid transformations and the linguistic ability to make the language changes.

b. Source Materials. Characteristics of foreign mapping are given in TM 5-248. Information concerning available maps and allied materials pertaining to foreign areas is given in appropriate U.S. Army Topographic Command map indexes, gazetteers, and lists of geodetic control data. Information concerning the availability of mapping data, reproducible map copy, aerial photography, aeronautical-charting data, and nautical-charting data of foreign areas is usually obtainable through engineer intelligence channels.

17-18. Gazetteers

a. Gazetteers (place-name indexes) are issued to higher headquarters only. Initial allowances per medium-scale map series are as follows:

Theater headquarters	25
Theater army headquarters	25
Army group headquarters	10
Field army headquarters	5
Corps Headquarters	2
Division headquarters	2

b. Production, storage, and distribution of gazetteers are identical with mapping responsibilities; in CONUS, the Corps of Engineers is responsible; in a theater of operations, the theater army engineer.

17-19. Trig Lists

a. Guides for Estimating Quantities of Trig Lists Required for Initial Issue.

(1) Trig lists (geodetic control point lists) should be distributed only to those units having requirement for geodetic data (i.e., staff engineers, engineer topographic units, artillery units, missile units, etc.).

(2) In addition to the guides stated in (1)

above, the following quantities are needed by units indicated.

Note. In most foreign countries, trig lists are classified CONFIDENTIAL.

	Unit	Number of trig lists
(a)	<i>Army group:</i>	
	Army group engineer	1
	Survey liaison detachment ...	1
(b)	<i>Field army:</i>	
	Field army engineer	1
	Engineer bn (army) (topo) ..	2
(c)	<i>Corps:</i>	
	Corps engineer	1
	Engineers co (corps) (topo) ..	2
	Corps artillery	10
	Per weapons bn	1
(d)	<i>Infantry division:</i>	
	Division artillery	8
	HHB	3
	FA bn, 105-mm (towed) (ea 1)	3
	FA bn, 155-mm (towed) 8-in. (SP)	1
	FA bn, HJ	1
	Division engineer	1
(e)	<i>Infantry division (mechanized):</i>	
	Division artillery	13
	HHB	3
	FA bn, 155-mm (SP) (ea 2)	6
	FA bn, 155-mm/ 8-in. (SP)	2
	FA bn, HJ	2
	Division engineer	1
(f)	<i>Armored division:</i>	
	Division artillery	13
	HHB	3
	FA bn, 155-mm (SP) (ea 2)	6
	FA bn, 155-mm/ 8-in. (SP)	2
	FA bn, HJ	2
	Division engineer	1
(g)	<i>Airborne division:</i>	
	Division artillery	6
	HHB	2
	FA bn, 105-mm (towed) (ea 1)	3
	Division engineer	1
(h)	<i>Airmobile division:</i>	
	Division artillery	7
	HHB	2
	Avn btry	1
	FA bn, 105-mm (towed) (ea 1)	2

Unit	Number of trig lists
FA bn, 105-mm (towed) (abn) -----	1
FA bn, aerial arty -----	1
Division engineer -----	1
(i) U.S. Army missile command. To be determined by the mission.	

b. Production of Trig Lists.

(1) *Responsibilities.* Compilation and printing of trig lists will normally be accomplished by

the U.S. Army Topographical Command (CONUS) and all military topographic units (theater of operations) having the necessary geodetic data and survey results for each station. Trig lists produced in CONUS are often revised to reflect new surveys and reproduced in the theater of operations by military topographic units.

(2) *Format.* Trig lists are bound publications of 1/4- to 1/2-inch thickness, with a trim size of 9 x 11 inches, and are printed on map stock, high wet-strength paper.

Section III. AERIAL PHOTOGRAPHY

17-20. Types

a. Types of Aerial Photos. Aerial photography may be classified according to the orientation of the camera axis (vertical or oblique), the lens system (single or multiple), and special properties (black and white, infrared, color, radar).

(1) *Vertical photo.* The scale of a vertical aerial photograph is not uniform throughout; areas of relief cause scale variations. However, photography over fairly flat terrain is nearly uniform in scale. Vertical photography is by far the most widely used for mapping and intelligence because the imagery is more easily converted to the orthographic projection of the map.

(2) *Oblique photo.* This is an aerial photo taken with the camera axis intentionally tilted from the vertical. The scale of an oblique photo decreases progressively from foreground to background. A high oblique photo is defined as one which includes part of the horizon while low oblique does not. Oblique photography is used principally because of the increased coverage over that of a vertical picture. This type is seldom used today for topographic map compilation.

b. Aerial Photo Coverage. The term "aerial photo coverage" denotes the ground area represented on existing aerial photos, and this is usually shown on a photo index or flight line index. Indexed photography makes it easier to see the relation of one picture to the other and its relation to the area covered as a whole. Planning data for flight plans are contained in TM 5-243. Coverage for intelligence purposes is as follows:

(1) *Basic cover.* Basic cover is complete photo coverage of a projected area of operations flown periodically or seasonally to fulfill general operational and intelligence requirements and to provide, with subsequent photography, a basis

for comparative photo studies. Basic cover usually extends from friendly forward dispositions to a depth of 160 kilometers or more, as required, into enemy-held territory. Basic coverage can normally be expected to be at a scale of 1:25,000.

(2) *Tactical cover.* Tactical cover is current vertical stereoscopic photography across the field army front extending from friendly forward dispositions to a depth determined by operational and intelligence requirements. The depth to which it is flown is usually determined by the maximum range of friendly artillery or by the location of selected objectives during an offensive operation. For maximum effectiveness, it should be at a scale of 1:10,000 or larger. Tactical cover is flown as requested by field army.

(3) *Special cover.* Special cover is photography specifically requested for special study of selected targets or critical areas to meet immediate information requirements of combat units. The scale and type of photography will vary, depending on the type of target and the information required.

17-21. Requirements for Aerial Photography

a. An initial issue of basic cover is made to field army units according to their requirements. Supplemental issues are made as required during the progress of the campaign. Typical initial issue of basic cover is shown in table 17-9.

b. Detailed planning data for determining the number of aerial photographs required to cover a given area are contained in TM 5-243 and TM 30-245. For general planning purposes, the minimum number of photographs required for stereoscopic coverage of an area at a desired scale can be determined by dividing the square meters of the area by the net gain per photograph. The

Table 17-9. Typical Initial Issue of Basic Cover—Aerial Photos

1	Unit or agency	2 Number of sets	3 Depth into enemy territory (km)	4 Number 9 x 9-in. photos		5 Total (approx lb)	
				1:25,000	1:10,000	1:25,000	1:10,000
2	Theater army, base topo bn	2 sets theater army area	480	40,000	248,000	1,332	8,266
3	Fld army G2 (air recon spt bn).	(Based on 160-km width) 2 sets fld army zone/sector.	480	20,000	124,000	666	4,133
4	Fld army topo bn	(Based on 160-km width) 1 set fld army zone/sector.	480	10,000	62,000	333	2,066
5	Fld army G2 (PI sec)	(Based on 160-km width) 1 set fld army zone/sector.	480	10,000	62,000	333	2,066
6	Corps G2 (PI sec)	(Based on 55-km width) 1 set corps zone/sector.	160	1,200	7,175	40	240
7	Corps topo co	(Based on 55-km width) 1 set corps zone/sector.	160	1,200	7,175	40	240
8	Corps arty (PI sec)	(Based on 55-km width) 1 set corps zone/sector.	160	1,200	7,175	40	240
9	Div G2 (PI sec)	(Based on 15-km width) 2 sets division zone/sector.	80	400	2,110	17	140
10	Div arty (PI sec) ¹	(Based on 15-km width) 1 set division zone/sector.	80	200	1,055	7	70
				ea div	ea div	ea div	ea div
				ea div	ea div	ea div	ea div
				arty	arty	arty	arty

¹ Attached to division from military intelligence battalion, field army.

minimum number of photographs should be increased by about 20 percent to allow for overedge coverage. The net gain planning factors are as follows:

- (1) For 9 x 18-inch photography:
Net gain = $1/40 S^2$ (S = denominator of scale of desired photography).
- (2) For 9 x 9-inch photography:
Net gain = $1/8 S^2$.

Example:

Given: An area 8,000 meters by 12,000 meters to be photographed at a scale of 1:5,000.

Find: The number of 9 x 18-inch photographs required.

$$\begin{aligned} \text{Solution: } & \frac{8,000 \times 12,000 \times 40}{(5,000)^2} \\ & = 154 \text{ photographs minimum.} \\ & 154 + 20 \text{ percent} = 185 \text{ total} \\ & \text{photographs required.} \end{aligned}$$

c. Table 17-10 may be used for initial rough estimates of aerial photo requirements.

17-22. Aerial Photo Reproduction and Photointerpretation Units

Functions of two sections of the military intelligence detachment TOE 30-7G of the military intelligence battalion, air reconnaissance support, field army (TOE 30-5G), are illustrated in *a* and *b*, table 17-11. Data on the functions of two Air Force photographic units are contained in *c*, table 17-11.

Table 17-10. Total Photo Requirements for a Field Army

1	Area	Cover (scale 1:10,000)			
		Basic ¹		Tactical ² (depth 25 km)	
		Photos	Wt/lb	Photos	Wt/lb
2	Field army zone/sector based on 160-km width).	Depth 21,600	160 km 728	1,600	96
3	Corps zone/sector (based on 60-km width).	Depth 3,640	80 km 255	480	34
4	Division zone/sector based on 15-km width).	Depth 1,560	40 km 108	160	11

¹ Based on issue table 17-9.

² Per set of photos.

Table 17-11. Aerial Photo Reproduction and Photointerpretation Units

a. Reproduction Section, Military Intelligence Detachment, Air Reconnaissance Support, Field Army (TOE 30-7G)

	1	2	3	4
1	Methods of reproduction	Sheet size	Remarks	Capabilities
2	Contact printing aerial photos from negatives.	9- x 9- or 9- x 18-inch prints.	Section reproduces, identifies, and distributes aerial imagery obtained from the tactical air force reconnaissance elements.	Reproduction, identification, packaging, and delivery of up to 4,000 9- x 18-inch prints of aerial imagery per operational period of 8 hours.

b. Imagery Interpretation Section, Military Intelligence Detachment, Air Reconnaissance Support, Field Army (TOE 30-7G)

	1	2
1	Remarks	Capabilities
2	Performs detailed interpretation of aerial imagery for the field army as required.	Plots and performs immediate interpretation of 950 9- x -8-inch air photographs (or the equivalent) in a 24-hour period, and prepares and disseminates priority interpretation reports on this imagery. Provides liaison with reconnaissance elements of the tactical air force that provide support to the field army; briefs and debriefs Air Force pilots to secure information obtained from visual sightings.

c. Air Force Photographic Units

	1	2	3
1	Unit	Photographs furnished	Remarks
2	Reconnaissance wing (theater of operations).	Specialized photography needed by topographic units for photogrammetry and photography for strategic purposes beyond the scope of reconnaissance wings of tactical air commands and tactical air forces.	Wing may include mapping and charting squadrons. Mapping photography ordinarily not suitable for intelligence image interpretation purposes because of small scale and lack of detail, may contain important information. Therefore, prints should be made available to military intelligence officers and units for study.
3	Reconnaissance wings of tactical air commands and tactical air forces.	Photographs needed for intelligence or combat purposes (single photographs, vertical and oblique; stereo-pairs; or night photographs).	Also visual reconnaissance missions are capable of providing limited vertical and oblique photographs. Photographic missions capable of large quantities of high-altitude vertical and oblique photographs and, under extremely urgent circumstances, limited and low-altitude vertical and oblique photographs.

CHAPTER 18

OTHER ENGINEER OPERATIONS

Section I. CIVIL DEFENSE AND DISASTER CONTROL

18-1. Role of the Armed Forces

a. The responsibility of the United States Armed Forces is primarily the protection of the United States from any hostile nation or group of nations. There are, however, other real and dangerous threats to the welfare of the United States that the Armed Forces must be prepared to meet. There is, for example, the constant threat of natural disasters that result in loss of life, property, and resources that are essential to the economic, political, and social welfare of the United States. There is also the constant threat that widespread civil disturbances present to the effective functioning of our government, to public

morale, to public relationships, and national progress.

b. The Department of the Army has primary responsibility among military services for providing assistance to civil authorities in civil defense, civil disturbances, and disasters, and for coordinating the functions of all military services in these activities.

18-2. Use of Army Organization for Military support of Civil Defense

The capability of Army organizations to perform the various tasks required in military support of civil defense is shown in table 18-1.

Table 18-1. Capabilities of Army Organizations for Military Support of Civil Defense

a. General.

Type of organization	Categories of capabilities											
	A	B	C	D	E	F	G	H	I	J	K	L
Adjutant general	--	--	O	--	O	--	--	O	O	--	--	--
Air cavalry	--	O	O	O	O	X	X	O	X	X	X	X
Armor	--	O	O	O	O	X	X	O	X	X	X	X
Armored cavalry	--	O	O	O	O	X	X	O	X	X	X	X
Army aviation	--	--	X	--	O	X	X	O	X	X	X	X
Army intelligence and security	--	O	O	O	O	X	X	X	X	X	--	X
Army training centers	--	O	O	O	O	--	O	O	X	X	--	X
Arsenals and depots (not part of an installation)	X	X	X	O	O	X	--	O	X	--	--	--
Artillery	--	O	O	O	O	X	X	O	--	X	X	X
Chemical	--	O	X	O	O	X	X	O	X	X	X	X
Civil affairs	X	X	X	X	X	X	X	X	X	X	X	--
Engineer	X	X	X	O	O	X	X	O	X	X	X	X
Finance	--	--	O	--	O	--	--	O	O	--	--	--
Hospitals	--	--	--	X	O	--	--	--	--	X	--	--
Infantry (to include mechanized infantry)	--	O	O	O	O	X	X	O	X	X	X	X
Installations (excluding U.S. Army garrison units or Army training centers located thereon)	X	X	X	X	O	X	X	O	X	X	--	--
Maintenance battalions	X	O	O	O	O	X	X	O	X	X	--	--
Medical	--	--	O	X	O	X	X	--	X	X	--	--
Military police	--	O	O	O	O	X	X	X	X	X	--	X
Ordnance	X	X	O	--	O	X	X	O	X	X	X	--
Psychological operations	--	--	--	X	O	--	X	X	X	X	--	X
Quartermaster	X	O	O	O	X	X	X	O	X	X	--	--
Recruiting stations	--	--	--	--	O	--	--	O	--	--	--	--
ROTC detachments	--	--	--	--	O	--	--	O	--	--	--	--
Service schools	--	O	O	--	O	X	X	O	X	--	X	X
Signal	X	O	O	O	O	X	X	O	X	X	--	X

Table 18-1. Capabilities of Army Organizations for Military Support of Civil Defense—Continued

Type of organization	Categories of capabilities											
	A	B	C	D	E	F	G	H	I	J	K	L
Special forces	--	--	--	O	O	--	O	O	O	X	X	X
Supply and transport battalions	X	X	O	O	O	X	X	O	X	X	--	--
Transportation	X	X	O	O	O	X	X	O	X	X	--	--
U.S. Army garrison units	--	O	O	O	O	--	X	O	X	X	--	--
Women's Army Corps	--	--	--	O	O	--	--	O	X	X	--	--

¹ X Particularly suited to this category because of the skilled personnel or special equipment normally available in the unit, or a combination of both.

O Can provide this type of support based on the organized manpower normally available in the unit rather than on any special skills or equipment.

b. Definition of the categories of capabilities are as follows:

Category	Capability
A	Restoration of facilities and utilities, including transportation, communications, power, fuel, water, and other essential facilities.
B	Emergency clearance of debris and rubble, including explosive ordnance from streets, highways, rail centers, dock facilities, airports, shelters, and other areas, as necessary, to permit rescue or movement of people, assistance to and recovery of critical resources, emergency repair or reconstruction of facilities, and other emergency operations.
C	Fire protection.
D	Rescue, evacuation, and emergency medical treatment or hospitalization of casualties, recovery of critical medical supplies, and safeguarding of public health. This may involve sorting and treating of casualties and preventive measures to control the incidence and spread of infectious diseases.
E	Recovery, identification, registration, and disposition of deceased personnel.
F	Radiological survey and decontamination, to include identifying contaminated areas and reporting information through the National Warning System. Initial decontamination will, of necessity, be directed primarily at personnel and vital facilities.
G	Movement control, to include plans and procedures for essential movements.
H	Maintenance of law and order, to include— a. General police and law enforcement operations. b. Emergency highway traffic control and supervision. c. Security and protection of vital facilities and resources. d. Enforcement of economic stabilization measures that may be required in the immediate postattack phase. e. Detection of subversive elements and liaison with civilian investigative agencies.
I	Issuance of food and essential supplies and materiel, to include collection, safeguarding, and issuance of critical items in the initial postattack phase.
J	Emergency provision of food and facilities for food preparation, if mass or community subsistence support should be required.
K	Damage assessment.
L	Provision of interim communications, using available mobile military equipment to provide command and control.

18-3. Staff Officers Checklists for Civil Disturbances

**CHECKLIST I
G1/S1 MAJOR AREAS OF STAFF
RESPONSIBILITY**

1. The G1/S1 has staff supervision over the following:

Adjutant General, including Postal Officer.
Chaplain.
Finance Officer.
Provost Marshal.
Surgeon.

2. The G1/S1 coordinates with the following

members of the commander's personal staff over whom he exercises no staff supervision:

Inspector General.
Staff Judge Advocate.
Information Officer.

G1/S1 MAJOR AREAS OF RESPONSIBILITY

1. Maintenance of unit strength
 - a. Strengths committed to the area of operations.
 - b. Personnel records.
 - c. Replacements for the area of operations.
2. Personnel management
 - a. Personnel procedures.
 - b. Handling of detainees in conjunction with civil authorities.
3. Morale and welfare
 - a. Personal services provided by the unit and available in the area of operations:
 - (1) Rest and recreational facilities.
 - (2) Character guidance and religious activities.
 - (3) Postal service.
 - (4) Special service activities.
 - (5) Exchange services.
 - (6) Financial services.
 - (7) Legal services.
 - (8) Medical services.
 - b. Decorations and awards.
4. Discipline, law and order, with special emphasis on directives published for civil disturbance control operations.
5. Headquarters management.
6. Safety programs to include special consideration for operations in cities.
7. Personnel aspects of estimates, plans, orders, and reports.
8. Administrative matters not assigned to another staff officer in civil disturbance control operations.
9. Casualty reporting.
10. Preparation of personnel and administration portion of unit SOP.

CHECKLIST II

G2/S2 MAJOR AREAS OF STAFF RESPONSIBILITY

1. Production of intelligence
 - a. Preparation of plans and orders for collection of information, to include aerial reconnaissance and surveillance units and local authorities.

b. Recommendation of essential elements of information and other intelligence requirements with emphasis on leaders and subversive activities.

c. Supervision and coordination of information collection activities (to include all civilian agencies).

d. Integration of information collection effort provided by civilian, other services, and other elements of Federal forces.

e. Weather data collection.

f. Processing of information into intelligence.

g. Determining map requirements through coordination with force staff.

2. Use of intelligence and information:

a. Estimate of the effects of the characteristics of the area of operations on the courses of actions, to include identification of landing zones for aircraft and helicopter.

b. Estimate of mob capabilities and vulnerabilities, including probable courses of action of large groups of civilians.

c. Preparation of intelligence estimates, annexes, reports, summaries, and studies.

d. Dissemination of information and intelligence to all agencies.

3. Counterintelligence: protection of sensitive information against unauthorized disclosure to the local population.

4. Requisition and distribution of maps and aerial photography of the community.

5. Preparation of order of battle information.

6. Preparation of intelligence portion of SOP.

CHECKLIST III

G3/S3 MAJOR AREAS OF STAFF RESPONSIBILITY

1. Organization

a. Compilation of troops lists.

b. Requests for assignment or attachment of tactical, tactical support, and administrative support units or teams.

2. Training

a. Preparation and execution of training programs, and the planning and conduct of field exercises.

b. Determination of requirements for training aids, facilities, and training ammunition.

c. Planning for, and conduct of training inspections and tests.

d. Organization and conduct of schools, and compiling training records and reports.

3. Operations

a. Preparation of operations estimate.

b. Preparation and publication of operations plans and orders to include instructions on degrees of force to be used.

c. Close supervision and coordination of riot control operations.

d. Review of plans for the following operations: road blocks and barricades, riot control munitions, communication in buildup areas, and civil affairs in the absence of a G5/S5.

e. Designation of command post areas collocated with police headquarters whenever possible.

f. Tactical troop movements, with emphasis on security and selection of routes and times of movement.

4. Preparation of operations portion of SOP.

5. Coordination of civil affairs activities if no G5/S5 section is assigned.

CHECKLIST IV

G4/S4 MAJOR AREAS OF STAFF RESPONSIBILITY

1. Supply

a. Requisition, storage, and issue of authorized special items of equipment.

b. Requisition, procurement, storage, security, distribution and documentation of all supplies.

c. Issue in accordance with allocations of those weapons and munitions which are regulated, or critical items of supply.

d. Collection and disposition of excess salvage, surplus, and confiscated material such as privately owned weapons and ammunition.

2. Medical services

Medical supply and maintenance.

3. Transportation and troop movements.

a. Administrative movement of personnel and materials.

b. Movement control in the area of disturbance.

c. Preparation of march order annexes and loading plans.

4. Service

a. Establishment of priorities for logistic support.

b. Maintenance and repair of supplies and equipment.

c. Food service.

d. Bath/shower.

e. Laundry.

f. Billeting.

g. Sanitation.

h. Real estate and facility acquisition.

i. Transportation.

5. Miscellaneous

a. Logistic administration, including preparation of logistic estimates, plans, and reports.

b. Preparation and distribution of administrative orders.

c. Logistic support of civil affairs policies.

d. Area damage control.

6. Preparation of logistic portions of unit SOP.

CHECKLIST V

G5/S5 MAJOR AREAS OF STAFF RESPONSIBILITY

1. The degree of military control, and the scope of the activities of the military commander in each of the areas indicated for which the G5/S5 has staff responsibility, are dependent on the authority vested in the military commander as outlined in the letter of instructions for the particular operation.

2. The G5/S5, when assigned to a staff, is the principal staff assistant to the chief of staff in matters pertaining primarily to the civilian population, its government, economy, and institutions in the area of operations. In addition, he has the responsibility for providing to other staff officers advice and assistance concerning the civil affairs aspects of functional areas and activities which are the primary responsibility of those officers.

3. The following functions, as appropriate under that authority, may be performed by the G5/S5:

a. Maintain direct liaison with and provide assistance to local governmental agencies.

b. Assist civilian authorities to exercise populace and resources control in coordination with

the Provost Marshal, in the following public safety activities:

- (1) Law enforcement measures.
- (2) Traffic regulations and enforcement of curfew.
- (3) Police and military patrols.
- (4) Prevention of pilferage and crime.
- (5) Control of public meetings, parades and demonstrations.
- (6) Firefighting.
- (7) Operation of confinement facilities.
- (8) Safeguarding of supplies, material, equipment, buildings, and critical areas.

c. In coordination with G4 and the Surgeon, assist civil authorities in public health and sanitation activities to include:

- (1) Determining availability and adequacy of medical and auxiliary medical personnel.
- (2) Administration or supervision of medical and sanitation facilities.
- (3) Care and disposition of civilian remains.
- (4) Protection of food and water supplies.
- (5) Disposal of sewage and waste.
- (6) Arrangement for preventive medical services.
- (7) Treatment of sick and wounded civilians.
- (8) Provision of medical transportation for sick, injured, or wounded civilians.

d. Assist civil governmental officials to determine necessary emergency relief supplies to include food, water, medical supplies, clothing, blankets, and fuel for the civilian population, estimate their availability, and in coordination with the G4 and Provost Marshal arrange for their procurement, storage, security and distribution.

e. Assist civil governmental officials in public welfare activities to include:

- (1) Providing collecting points, emergency shelters and feeding centers for civilians requiring evacuation or whose homes have been destroyed.
- (2) Procuring necessary manpower to support these emergency relief activities.

f. Determine the location, type and availability of local materials necessary for conducting operations within the area and coordinating with G4/S4 in the procurement of same.

g. Conduct surveys of the organization, routes and capabilities of the public transportation system, including extent of damage and requirements for its restoration.

h. In coordination with the Information Offi-

cer, assist governmental authorities to prepare and disseminate information through the established communication media.

i. Assist local authorities, or recommend necessary command action to evacuate civilians to preclude their interference with operations and/or to insure their safety.

j. Recommend to the commander the numbers and types of Civil Affairs units and their functional team compositions required to support operations.

CHECKLIST VI INFORMATION OFFICER MAJOR AREAS OF RESPONSIBILITY PRIOR TO OPERATION (LONG RANGE)

1. Info plan to support operation on 24-hour basis.
2. Personnel assignments.
3. Equipment status:
 - a. Typewriters.
 - b. Mimeograph.
 - c. Still cameras.
 - d. Motion picture cameras.
 - e. PA system.
 - f. Generator (if necessary).
 - g. Lights sets for TV.
 - h. Tape recorders.
4. Disseminate command guidance for release of public information.
5. Plan for information officer space to include pressroom/newscenter near proposed CP.
6. Supervision and coordination of use of psychological operations elements.

IMMEDIATELY PRIOR TO OPERATIONS

7. Command Info Fact Sheet to include:
 - a. Situation background.
 - b. Organization mission and command structure.
 - c. Relationship to civilian authorities.
 - d. Relationship to civilians in disturbances.
 - e. Troop conduct en route to and during operations.
8. Liaison with city, state, and other official public affairs officials.
9. Set up pressroom.
10. Press registry and ID system (as necessary).
11. Establish newsclip files for story releases and statements released.

12. Liaison with all news media.
 - a. Assist them to cover events.
 - b. Allow freedom of movement if not interfering with operations.
13. Rapid response to press queries.
14. Feed of news from subordinate units as appropriate.
15. Press conference schedule.
16. Daily mimeographed command information news bulletin.

18-4. Characteristics and Employment Considerations of Riot Control Agents and Smoke in Civil Disturbance Operations

- a. The employment of riot control agents and smoke in a disturbance depends upon the physical and chemical properties of the agents, their intended uses and methods of dissemination.
- b. Tables 18-2 through 18-4 list the riot control agents or smoke munitions and their characteristics that are employed in civil disturbance operations.

Table 18-2. Characteristics of Riot Control Agents (CS) and Smoke (HC)

	CS		HC
	Burning type	Powder type	
Composition	CS; potassium chlorate; thiourea; magnesium carbonate.	Micropulverized CS; silica aerogel.	Hexachlorethane; zinc oxide.
Odor	Pungent; pepperlike	Pungent; pepperlike	Like camphor.
Persistency (in open)	Variable according to wind conditions.	Variable according to wind conditions; greater with lack of wind or in wooded terrain.	Variable according to wind conditions; maximum 10 minutes.
Minimum effective protection.	Protective mask; field clothing	Protective mask; field clothing	None needed.
Physiological action	Extreme burning sensation of the eyes; copious flow of tears; coughing, difficult breathing, and chest tightness; involuntary closing of eyes; stinging action on moist skin areas; sinus and nasal drip; nausea and vomiting on exposure to extreme concentrations (via ingestion).	Extreme burning sensation of the eyes; copious flow of tears; coughing, difficult breathing, and chest tightness; involuntary closing of eyes; stinging action on moist skin areas; sinus and nasal drip; nausea and vomiting on exposure to extreme concentrations (via ingestion).	Slightly suffocating action in heavy concentration; slightly irritating to nose and throat.
Time required for maximum effort.	Immediate	Immediate	Effect negligible.
First aid	Remove to uncontaminated area; face into wind; caution against rubbing eyes; keep affected persons well spaced; shower after several hours. Shower first with cool water for 3 to 5 minutes then proceed with normal showering. For gross accidental contamination with CS particles, flush body with copious amounts of cool water, then use a 5% sodium bisulfite solution (except in and around eyes) and finally flush again with water. A 1% solution of sodium carbonate or sodium bicarbonate may be substituted for sodium bisulfite solution.	Remove to uncontaminated area; face into wind; caution against rubbing eyes; keep affected persons well spaced; shower after several hours. Shower first with cool water for 3 to 5 minutes then proceed with normal showering. For gross accidental contamination with CS particles, flush body with copious amounts of cool water, then use a 5% sodium bisulfite solution (except in and around eyes) and finally flush again with water. A 1% solution of sodium carbonate or sodium bicarbonate may be substituted for sodium bisulfite solution.	None needed.
Type of munitions	Grenades, hand and rifle	Grenades, hand	Grenades, hand; pots, smoke.
Mechanically dispersable	No	Yes	No.

Table 18-3. Statistics—Riot Control Agent Grenades, Smoke Grenades and Smoke Pots

	Grenade, hand, CS, M7A2**M7A3	Grenade, hand, CS1, M25A2
Filling	CS mixture	CS1 mixture.
Weight of effective filling	9.7 ounces	3.2 ounces.
Weight of complete munition	16 ounces	7.25 ounces.
Fusing delay	0.7 to 2 seconds. m	1.4 to 3 seconds.
Burning time	15 to 35 seconds	Bursts.
Persistency in open	Variable according to wind conditions ..	Variable according to wind and terrain conditions.
Area coverage	100-150 sq meters (one munition; wind speed 9-15 mph).	600-900 sq meters (three munitions; wind speed 12-18 mph).
Effective downwind	35 meters (one munition; wind speed 9-15 mph).	40-90 meters (three munitions; wind speed 12-18 mph).
	Grenade, hand, smoke, HC, AN-M8*	Pot, smoke, HC, M5
Filling	Type C HC smoke mixture	Type C HC smoke mixture.
Weight of effective filling	19 ounces	28-34 pounds.
Weight of complete munition	25.5 ounces	33 pounds.
Fusing delay	1.2 to 2 seconds	20 to 30 seconds.
Burning time	105-150 seconds	12 to 22 minutes.
Persistency in open	Variable according to wind conditions ..	Variable according to wind conditions; maximum 10 minutes.
Persistency in halls	15 minutes	45 minutes.
Persistency in closed rooms	1 hour	1 ½ hours.
Maximum range of cloud from one munition (average conditions).	200 meters	500 meters.

* These hand grenades may be converted into rifle grenades with the use of the grenade projection adapter, chemical, M2.

** This hand grenade may be converted into a rifle grenade with the use of the grenade projection adapter, chemical, M2A1.

Special Precaution: These grenades and smoke pots are burning type munitions. If they are ignited in close proximity to easily combustible material, fires are likely to result.

Note. These data reflected in this table are furnished only as an approximate guide.

Table 18-4. Minimum Burning Ammunition Requirements for Riot Control Agents Used in Large Scale Disturbances¹

Width of initial cloud front all munitions distributed evenly and fired simultaneously on the front	250 meters downwind		500 meters downwind		1,000 meters downwind	
	Number of munitions required ²	Width of cloud ³	Number of munitions required ²	Width of cloud	Number of munitions required ²	Width of cloud
	<i>Burning type hand grenades</i>		<i>Burning type hand grenades</i>		<i>Burning type hand grenades</i>	
		<i>Meters</i>		<i>Meters</i>		<i>Meters</i>
Point	4	50	25	100	.....	.....
25 meters	6	75	25	125	50	225
100 meters	20	150	50	200	75	300
250 meters	40	300	80	350	120	450
	<i>Pot, smoke HC</i>		<i>Pot, smoke HC</i>		<i>Pot, smoke, HC</i>	
Point	1	50	1	100	.....	.....
25 meters	2	75	2	125	7	225
100 meters	5	150	5	200	10	300
250 meters	12	300	12	350	18	450

¹ These data, furnished only as an approximate guide, are generally acceptable under average conditions (TM 3-240). Excessively high winds preclude the use of clouds, as do low and intermittent winds. Does not refer to exploding type grenades.

² These numbers may be increased advantageously, when available ammunition permits.

³ Maintenance of a cloud until dispersion of the mob is effected should be attempted; a short heavy concentration is preferable to a sustained light concentration.

18-5. Detailed Information

For detailed information on civil defense and disaster control refer to FM 19-15 and FM 20-10.

Section II. PW INCLOSURES

18-6. General

FM 27-10 sets forth the general provisions by which our forces will be governed in dealing with enemy personnel. TM 19-500 discusses the treatment and processing of prisoners of war and the security measures pertaining to them. TM 5-301, TM 5-302, and FM 101-10 contain additional details on PW inclosures.

18-7. General Provisions

a. Prisoners of war must be lodged in buildings or barracks which are healthful, dry, heated, lighted, and protected from fire. Minimum dormitory area and air-space requirements will be the same as for troops at base camps.

b. Prisoners of war will have constantly at their disposal installations conforming to sanitary rules, including the best practicable provisions for baths and showers. They must be enabled to take physical exercise and enjoy the open air. Sexes must be segregated.

c. In a theater of operations, prisoners of war will be sheltered in existing facilities when possible. If facilities must be built, they will be of temporary construction. For economy in area and fencing, buildings are best grouped in the center of the inclosure and space between them and deadline fences used for open air and exercise.

d. Prisoner-of-war labor will be used to the maximum in establishing, converting, maintaining, and dismantling security and housing facilities for themselves and their guards. They will not receive wages for work connected with installing, maintaining, or administering the camps.

18-8. Security Provisions

a. Stockage fences (except high masonry walls or impassible terrain features) are temporary barriers only, to delay escape attempts and the entrance of unauthorized persons or contraband articles long enough to permit guards on towers or perimeter patrols to act.

b. Stockage fences of the following types are considered satisfactory:

(1) A single chain-link woven steel-wire fence (2-inch mesh, 6- to 9-gage wire) not less than 8 feet high, with top 45° extension arms carrying three strands of barbed wire, and with barbed-wire concertinas anchored to the ground outside the fence.

(2) Two fences of the above type set 8 to 10 feet apart, with barbed-wire concertinas fastened to the top of the outer fence.

c. The delaying effect of the stockage fence is substantially increased by installing a deadline fence (a barbed-wire fence about 3 feet high which prisoners of war are forbidden to cross) about 8 to 10 feet inside the inner stockade fence.

d. Normally one gateway for one-way vehicular traffic, with a wicket for pedestrians, is adequate.

e. Guard towers with lights are installed to improve observation and to permit enflading fire along fences and streets and inside the stockade.

18-9. Sequence of Development

Prisoner-of-war inclosures are normally initiated in each army and task force service area, reverting to communications zone control and operation as the army rear boundary is advanced. Information for estimating the number likely to be captured is given in FM 101-10-1. Priority of other work in forward areas is likely to restrict construction, and initial prisoner-of-war inclosures will normally consist of existing buildings or tents, for shelter, pit type latrines, expedient facilities for cooking and bathing, and a stockade fence. Such facilities should be designed for full development later by prisoner-of-war labor.

18-10. Prisoner-of-War Camp Standards

Estimates are based on four standards (table 18-5) of permanence (2, 3, 4, and 5) as follows:

a. *Standard 2.* Class IV tents with earth floors for all facilities. Bucket type latrines. Engineer effort consists of construction of security fencing, guard towers, water lines, and stabilized roads. Open ditch drainage.

b. *Standard 3.* Buildings for bathhouse, kitchen, latrines, and generators. All other facilities in tents. Concrete floors in buildings and tents. Electricity to all buildings and tents except PW housing. Floodlights. Other construction as in standard 2.

c. *Standard 4.* All buildings except PW housing. Electricity to all facilities. Drainage piped. Other construction as in standard 3.

d. *Standard 5.* All accommodations in buildings. Other construction as in standard 4.

Table 18-5. PW Camp Construction Requirements

	1	2	3	4	5	6	7	8	9	10	11
1	Standard	Size (number of PW)	Electric (kw)	Water (M gal per day)	Site area (sq m)	With steel-frame buildings			With wood-frame buildings		
						STON	MTON	Man- hours	STON	MTON	Man- hours
2	2 *	250	----	1.25	40,000	----	----	-----	95	113	6,060
3	-----	500	----	2.50	72,000	----	----	-----	142	177	10,420
4	-----	1,000	----	5.00	92,000	----	----	-----	196	265	13,710
5	-----	2,000	----	10.00	160,000	----	----	-----	290	374	22,740
6	-----	4,000	----	20.00	376,000	----	----	-----	565	786	60,860
7	Oriental	4,000	----	20.00	332,000	----	----	-----	482	687	51,900
8	3	500	39.9	5.00	72,000	269	383	19,720	283	389	20,360
9	-----	1,000	65.9	10.00	92,000	441	639	29,770	461	613	31,240
10	-----	2,000	126.8	20.00	160,000	728	1,068	54,030	766	1,082	56,230
11	-----	4,000	394.0	40.00	376,000	1,613	2,422	130,810	1,704	2,446	135,250
12	Oriental	4,000	283.0	40.00	332,000	1,160	1,916	102,360	1,313	2,088	105,640
13	4	500	44.0	5.00	72,000	372	533	25,970	391	531	27,160
14	-----	1,000	73.1	10.00	92,000	620	890	39,960	648	881	41,920
15	-----	2,000	138.3	20.00	160,000	1,047	1,878	75,800	1,159	1,565	81,120
16	5	500	47.6	5.00	72,000	478	729	30,590	532	714	34,950
17	-----	1,000	73.3	10.00	92,000	808	1,249	48,970	895	1,215	56,370
18	-----	2,000	145.5	20.00	160,000	1,471	2,279	93,190	1,638	2,203	108,470
19	-----	4,000	430.4	40.00	376,000	2,951	4,631	199,150	3,283	4,486	227,110
20	Oriental	4,000	303.2	40.00	332,000	1,794	2,875	136,960	1,953	2,848	148,250

* Tentage material used.

Section III. ENGINEER RECONNAISSANCE

18-11. General

Engineer reconnaissance, which is terrain reconnaissance conducted to support engineer activities, is designated as either general or special. General engineer reconnaissance provides engineer information of a broad nature within the operational area and is concerned with locating and evaluating those items, such as construction material, resources, and terrain features, which have engineer implications. General reconnaissance missions may be assigned on a zone, area, or route basis. Special engineer reconnaissance, on the other hand obtains more detailed information regarding a specific engineer task or tasks; normally, such reconnaissance follows and supports general engineer reconnaissance. Special reconnaissance may be assigned as either an area or route reconnaissance mission.

18-12. Engineer Reconnaissance Techniques

When general or special engineer reconnaissance is assigned as a route reconnaissance mission, appropriate procedures and reconnaissance techniques outlined in FM 5-34, FM 5-36, and GTA 5-2-1 are followed. Moreover, engineer reconnaissance is often conducted in conjunction with deliberate route reconnaissance in order to determine route conditions (including work estimates) and to locate construction material by which the route may be improved or maintained. The technical nature of engineer reconnaissance requires the issuance of detailed reconnaissance instructions. The results of engineer reconnaissance are usually reported on an overlay similar to the route reconnaissance overlay. DA Form 1711-R (Engineer Reconnaissance Report) and appropriate DA Forms 1248 (Road Reconnaissance Report), 1249 (Bridge Reconnaissance Report), 1250 (Tunnel Reconnaissance Report), 1251 (Ford Reconnaissance Report), and 1252 (Ferry Reconnaissance Report) supplement the reconnaissance overlay.

18-13. Engineer Reconnaissance Checklist

Important engineer aspects that should be considered in an engineer reconnaissance are listed below:

- a. Roads: Classify using symbols.
- b. Bridges, Fords, and Ferries: Classify using symbols. Possible by-pass for existing crossings.

Table 18-6. Suggested Items to Accompany Route Reconnaissance Patrol

Item	Quantity
Truck, utility, ¼ ton, 4x4	2
*Carrier, personnel, armored	2
Trailer, amphibious, cargo, ¼ ton	1
Machine gun, 7.62 mm	1
Pedestal, 7.62 mm machine gun mount	1
Launcher, grenade, 40 mm	1
Binocular 7x50	2
Goggles, sun, plastic	6
Radiacmeter, IM-93/UD	1
Radiacmeter, IM-174/PD	2
Detector kit, chemical agent, VGH, AN-M15A1A.	1
Paper, chemical agent detector, VGH, ABC M8.	1 bk
Wrist watch	2
Radio set AN/VRC-47, mounted in truck, ¼ ton.	1
Radio set AN/PRC-25	1
Flashlight	4
Lensatic compass	2
Clinometer	1
Panel marking sets	2
Pioneer tools	1 set/vehicle
Towing chain	2
Material for marking fording and swimming sites.	As required
Improvised means of measuring water depths.	1
Measuring tape	2
Three-man pneumatic reconnaissance boat.	1
Vehicular first aid kit	2
FM 5-34	1
Reconnaissance report forms and formats	As required
Adequate map and aerial photo coverage	As required
Tracing tape (tape, textile)	As required
Camera (polaroid)	1

* Desirable when operating in support of mechanized forces or in northern areas.

c. Obstacles to Our Movement: natural and artificial: include demolitions, mines, boobytraps.

d. Terrain: general nature, ridge system, drainage system including fordability, forests, swamps, areas suitable for mechanized operations.

e. Engineer Materials: Particularly road material, bridge timbers, lumber, steel, explosives.

f. Engineer Equipment: rock crushers, sawmills, garages, machine shops, blacksmith shops, etc.

g. Errors and Omissions on Maps Used.

h. Barriers to enemy movement: natural, ar-

tificial and sites for construction or improvement. (Work estimates)

- i.* Water Points: recommended locations.
- j.* Streams: general description, width, depth, banks, approaches, character of bottom, means to be used at possible crossing sites, navigability.
- k.* Defensive Positions.
- l.* Bivouac Areas: entrances, soil, drainage, sanitation, concealment.
- m.* Petroleum Storage and Equipment.
- n.* Utilities: water, sewage, electricity, gas.
- o.* Ports: wharves, sunken obstacles, cargo

handling facilities, storage facilities, transportation routes.

p. Construction Sites: drainage, water supply, power source, earthwork, access, acreage, soil.

18-14. Personnel and Equipment

a. There are many variations in the scope of reconnaissance; therefore, it is not practical to prescribe the composition of a standard patrol. A possible patrol would be composed of a patrol leader, assistant patrol leader, a radio operator/recorder, two drivers, and a machine gunner/observer.

b. Table 18-6 lists suggested items to accompany a route reconnaissance patrol.

Section IV. TERRAIN INTELLIGENCE AND MILITARY HYDROLOGY

18-15. Purpose of Terrain Intelligence

The purpose of terrain intelligence is to obtain data about terrain, weather and climate in order to assist the commander in making decisions and the troops in attaining their missions. FM 30-10 contains detailed information on this subject.

18-16. Engineer Responsibilities

Under the general staff supervision of G2 the staff engineer, or the senior engineer commander in the event a staff engineer is not authorized, carries out the terrain intelligence functions. He produces and maintains terrain studies based upon terrain analyses. This involves—

- a.* Determining the requirements for terrain information, based upon requests from G2.
- b.* Collecting and evaluating terrain information.
- c.* Assembling terrain intelligence into a terrain study. He provides technical interpretation of the terrain covering such factors of military significance as obstacles, routes, and avenues of approach, cover and concealment, landforms, hydrology, cross-country movement, and related subjects. He also disseminates terrain studies and technically evaluated information.

18-17. Sources and Agencies

The following are sources where terrain intelligence can be obtained.

- a.* Maps are the basic source of terrain information and are considered intelligence docu-

ments. The following are map types used for terrain intelligence:

- (1) Soil maps.
- (2) Geologic maps.
- (3) Communication maps.
- (4) Relief maps.
- (5) Pictomaps.
- (6) Specialized maps (vegetation, hydrographic charts, town plans, etc.).
- b.* Terrain models.
- c.* Photographs and remote sensor imagery.
- d.* Books and periodicals (atlases, tide tables, etc.).
- e.* Intelligence reports (NIS, EIS, LOC, engineer reconnaissance reports, etc.).
- f.* Captured enemy documents.
- g.* Interrogation.
- h.* Collection agencies.
 - (1) Troop units.
 - (2) Individual soldiers.
 - (3) Aircraft.
 - (4) Special agencies (MI units, Civil Affairs units, etc.).

18-18. Terrain Study Checklist

The following is a checklist which outlines what should be included in a terrain study.

- a.* Purpose and limiting factors.
- b.* Synopsis, brief statement on the effect the terrain has on military operations.

c. Climatic conditions—Present and future meteorological conditions.

- (1) Temperature—ranges and fluctuations.
- (2) Precipitation—frequency, type, and amount.
- (3) Winds—velocities and directions.
- (4) Visibility—times of sunrise, sunset and twilight; effect of fogs, mist, and haze, and visibilities distances.
- (5) Cloudiness—frequency of various cloud condition occurrences.
- (6) Humidity.
- (7) Electrical disturbances.

d. Topography—describe, if pertinent, the following:

- (1) Relief and drainage.
- (2) Vegetation—location, type, and density.
- (3) Surface materials—type and distribution of soils, subsoils and rock, trafficability.
- (4) Manmade features—roads, bridges, etc.
- (5) Special features, earthquake zones, active volcanoes, etc.

e. Coastal hydrology—describe when applicable.

- (1) Sea approaches—gradients, bottom conditions, etc.
- (2) Beaches—dimensions, trafficability, and exits.
- (3) Tides and currents—time of occurrence, direction, velocity, and duration.
- (4) Sea and surf—height of sea; type, width, height, and duration of surf.

f. Military aspects of terrain.

- (1) Tactical aspects.
 - (a) Observation.
 - (b) Fields of fire.
 - (c) Concealment.
 - (d) Cover.
 - (e) Obstacles.
 - (f) Movement.

(g) Key terrain features.

(h) Avenues of approach.

(2) Engineering aspects of terrain.

- (a) Construction sites.
- (b) Construction materials.
- (c) Water supply.

18-19. Water Supply

a. Water may be obtained from wells, streams, springs, lakes, and municipal or other supplies that are readily developed.

b. The information required in terrain intelligence studies includes the following:

(1) *General.*

- (a) Normal level of water table and variations.
- (b) Yield of springs and wells, and varies.
- (c) Potability and contaminations.
- (d) Underground flow in dry water-courses.

(2) *Surface supplies.*

- (a) Total drainage area.
- (b) Rainfall and runoff data.
- (c) Sources and kinds of possible contamination, including sewage or industrial wastes.
- (d) Chemical and bacteriological analyses.

(3) *Wells.*

- (a) Rainfall data.
- (b) Reports of available well logs and test data.
- (c) Physical, chemical, and bacteriological analyses.

(4) *Existing water supply system.*

- (a) Source of supply.
- (b) Quantity provided; ultimate capacity.
- (c) Treatment methods.
- (d) Distance from supply to proposed military user point.
- (e) Pressures.
- (f) Chemical and bacteriological analyses.

Section V. FIREFIGHTING

18-20. General

Firefighting is divided into three distinct branches.

a. The first, fire prevention, is the branch which establishes standards and practices for the prevention of accidental fires. These standards

and practices are controlled by frequent surveys and inspections. Responsibility for inspections and for recommending corrective action is vested in the fire protection organization.

b. Fire safety, the second branch, establishes standards and prescribes practices for the safe

occupancy and escape of personnel under fire and other emergency conditions. These standards and practices are controlled by frequent inspections and tests, the responsibility for which is also vested in the fire protection organization.

c. Fire protection, the third branch, establishes standards and procedures for control and extinguishment of fire, including protecting exposures, rescue of personnel, and salvage operations. These practices are controlled by written SOP's, practice drills, and inspections by the fire protection organization.

18-21. Organizations

The firefighting units provide prevention and protective measures, extinguish fires, train auxiliary firefighters, maintain firefighting equipment, and advise higher commanders of fire defense plans. The firefighting units consist of four types of teams (TOE 5-510G). These units are designated to provide organizations, which differ in size, with firefighting teams depending on tactical and logistical considerations involved. Command and administrative control are normally provided by the firefighting headquarters team.

a. Team FA, Firefighting Headquarters.

(1) *Capabilities.* Plans for overall strategic fire defense. Controls firefighting teams assigned or attached.

(2) *Basis of allocation.* Normally one per three to five firefighting teams, and one water truck team.

(3) *Strength.* Officer 1; EM 3; Agg 4.

(4) *Equipment.* Portable fire extinguishers, extinguisher repair and filling kit.

b. Team FB, Fire Truck.

(1) *Capabilities.* Provides fire protection and implements fire protection program for area housing 5,000 to 10,000 troops or warehouses and open stockpile storage of 100,000 square feet.

(2) *Basis of allocation.* One per post, base, camp or station housing 5,000 to 10,000 troops, or warehouses or open storage area of 100,000 square feet.

(3) *Strength.* EM-6, Agg-6.

(4) *Equipment.* Firefighting equipment set, truck mounted, structural type, oversea, class 530B.

c. Team FC, Water Truck.

(1) *Capabilities.* Transport water for fire-

fighting purposes when insufficient water is available.

(2) *Basis of allocation.* One per firefighting headquarters; additional as required.

(3) *Strength.* EM-2, Agg-2.

(4) *Equipment.* Truck, 2½ ton; 1000 gallon water tank, 6x6.

d. Team FD, Brush Fire Truck.

(1) *Capabilities.* This team, when augmented by volunteer personnel with handtools, furnishes protection against grass or brush fires within the assigned area of operation and can also be utilized to a limited degree to combat structural fires.

(2) *Basis of allocation.* (As required) One per post, base or station housing 5,000 to 10,000 troops or warehouses and open storage of 100,000 square feet.

(3) *Strength.* EM-2, Agg-2.

(4) *Equipment.* Firefighting equipment set, truck mounted, brush type, oversea, class 530B.

18-22. Classes of Fire

Fires are divided into four main classes: class A, class B, class C, and class D fires. These classes are based on the combustion characteristics of the ignited material. In most cases, installation fires are combinations of at least two, and sometimes all of these classes.

a. *Class A Fires.* Class A fires are fires in ordinary combustible materials such as bedding, mattresses, dunnage, books, cloth, canvas, wood and paper. Class A fires must be dealt with by cooling the fire below its ignition temperature. All class A fires leave embers which are likely to rekindle if air comes in contact with them. Therefore, a class A fire must not be considered extinguished until the entire mass has been cooled thoroughly. Smothering is not effective for class A fires because it does not lower the temperature of the burning embers below the surface of the fire.

b. *Class B Fires.* Class B fires are those which occur in flammable substances such as gasoline, jet fuels, kerosene, oils, paint, turpentine, grease, tar, and other combustible substances which do not leave embers or ashes. Class B fires can be extinguished by providing a barrier between the burning substance and the air or oxygen necessary for its combustion. Chemical and mechanical foam produce such barriers, and are known

as "permanent" smothering agents. Carbon dioxide is also a smothering agent, but its effect is only temporary and the application must be renewed if there is any danger of reignition.

c. Class C Fires. Class C fires are fires in live electrical materials. They present an extra hazard to the firefighter, because of the danger of electrical shock. A nonconducting extinguishing agent is essential for fighting class C fires. An additional consideration in fighting class C fires is the fact that it may be quite important to avoid damaging the electrical equipment in the process of extinguishing the fire. Electrical instruments and contacts will be contaminated by an extinguishing agent except gases. The first step in extinguishing a class C fire is to secure the source of power to the circuit, or equipment on fire. The preferred agent in fighting class C fires is carbon dioxide or monobromotrifluoromethane, since they give protection against electrical shock and are not likely to injure the equipment. Water fog, although not preferred, may be used; under ordinary conditions it does not transmit electricity

to the firefighter (as would a solid stream of water), but it may damage the energized electrical equipment.

d. Class D Fires. Class D fires are fires in combustible metals, such as titanium, zirconium, sodium, potassium, etc. The greatest hazard exists when these metals are in the molten state or in finely divided forms of dust, trimmings, or shavings. Ordinary extinguishing agents are ineffective on these metal fires, and they are best controlled by covering with special dry powdered or granular materials which exclude oxygen and which will not react or combine adversely with metal.

18-23. Fire Extinguishers

Table 18-7 covers fire extinguishers and outlines the classes of fire for which they can be used.

18-24. Additional Information

Firefighting (structures and aircraft) and rescue operations in the theater of operations are discussed in TM 5-315 and TM 5-687.

Table 18-7. Fire Extinguisher Types, Sizes, and Uses

Type	Size a/or weight	Fire class use ¹	Monthly inspection items	Remarks
Carbon dioxide	2-100 lb, 15 lb is most common	Class B and C	Hose and horn, wire and lead seal	Do not expose to extreme heat, must be winterized for temperatures below 0° F. ²
Pump type water	2½ gal, 4 gal, 5 gal.	Class A	Contents and quantity, hose and nozzle	Winterize
Pressurized water	2½ gal		Air pressure gage (100 psi) hose and nozzle, wire and lead seal	
Soda-acid			Contents, hose and nozzle	
Foam		Class B	Contents and quantity, hose and nozzle	Will hold 3 gal, never fill with more than 2½ gal
Dry chemicals	2½-150 lb	Class B, C, and D	Air pressure gage (150 psi) quantity (by weighing), wire and lead seal	Two types, one 150 psi dry nitrogen or air, other cartridge with CO ₂ under high pressure
Bromotrifluoromethane (CF ₃ Br)	2¾ lb	Class B, C, and D	Quantity (by weighing), wire and lead seal	Should not be stored where ambient temperatures exceed 150° F.
Chlorobromomethane (CBM)	1 qt, 1 gal	Class B	Air pressure gage (100 psi) hose and nozzle, wire and lead seal	Should be used with caution as it produces toxic chemicals when used on fires

¹ See paragraph 18-22 for description of classes.

² See TM 5-815 for proper winterizing procedures.

Section VI. SAWMILLS

18-25. Engineering Service Organization, Forestry Team GD

The engineer service organization, forestry team GD, is organized under TOE 5-520G. It has the necessary personnel and equipment to perform maintenance of its equipment, and logging, hauling, milling, and yarding operations. The team is capable of producing 10,000 to 15,000 board feet of rough lumber and timber per day. The team normally is assigned to an engineer forestry company.

18-26. Trailer Mounted Sawmill

The standard Army sawmill is diesel-engine-driven, semitrailer-mounted, with a circular 60-inch diameter blade. It consists of a log deck, log stop, carriage track, carriage husk, headsaw, sawdust-removal system, lumber rolls, diesel engine, a running gear, and a skid-mounted, diesel-engine-powered, 3-saw edger. The sawmill will saw logs up to 36 inches in diameter and twenty feet in length and will produce not less than 1,200 feet board measure (fbm) of 1-inch rough lumber per hour from No. 1 green oak logs 14 to 24 inches in diameter. This production rate can be achieved with a crew of seven men.

18-27. Portable Sawmill

The portable sawmill issued to forestry teams is

the Northeast Ohio Machine Builders model PN 25. The sawmill is designed to saw rough lumber from softwood and hardwood logs at a rate of 10,000 to 30,000 board feet of lumber per day. It is powered by a diesel engine which also powers a hydraulic motor attached to a wire rope drum which moves the carriage past the saw.

18-28. Crew Operations

a. Portable Sawmill Crew. A suggested crew for the portable sawmill consists of 14 to 16 men, depending upon local conditions. When large, uneven logs are being handled, additional men will be needed on the log skids. With small or medium-sized straight logs, one man can usually handle the log skids. Two to four men are required to take the lumber from the edger and cutoff rig, depending upon the sizes of lumber and the distance to the yard.

b. Trailer Mounted Sawmill Crew. The minimum crew size for the trailer-mounted sawmill is five men: a sawyer, two log deckmen and two off-bearers.

18-29. Standing Trees

Tables 18-8 and 18-9 outline the volume of standing trees. These tables can be used to estimate board feet available in a stand of timber.

Table 18-8. Amount of Saw Timber in Hardwood Trees of Different Diameters and Merchantable Heights

Diameter of tree, breast high (inches)	Number of 16-foot logs									Diameter of top (inside bark) (inches)	Basis for this table (trees)
	1	1½	2	2½	3	3½	4	4½	5		
	Volume* in board feet										
8-----	20	27	35	43	----	----	----	----	----	6	
9-----	20	32	42	53	----	----	----	----	----	6	1
10-----	20	36	52	64	81	----	----	----	----	6	2
11-----	21	43	62	78	98	120	----	----	----	6	4
12-----	23	50	73	93	120	140	180	----	----	6	3
13-----	25	58	86	110	140	170	200	----	----	7	4
14-----	27	67	100	130	160	190	230	260	----	7	9
15-----	30	77	120	150	180	220	260	300	----	8	15
16-----	34	89	130	170	200	250	290	340	390	8	18
17-----	38	100	150	190	230	280	320	380	440	9	40
18-----	43	120	170	210	260	310	360	420	490	9	56
19-----	48	130	200	240	290	350	400	470	540	10	65
20-----	54	150	220	270	330	390	450	520	590	10	75
21-----	62	170	250	300	370	440	500	580	650	11	86
22-----	69	190	270	340	410	480	550	640	720	11	90
23-----	77	210	300	380	450	530	610	700	790	12	67
24-----	85	230	340	420	500	580	670	770	860	12	80
25-----	93	250	370	460	550	640	740	840	940	13	56
26-----	100	280	410	510	600	700	810	910	1,020	13	89
27-----	110	300	450	560	660	770	880	990	1,110	14	68
28-----	120	330	490	610	720	830	960	1,080	1,200	14	81
29-----	130	360	530	660	780	900	1,030	1,160	1,300	15	61
30-----	140	390	580	720	850	980	1,120	1,250	1,400	15	47
31-----	---	420	630	770	910	1,050	1,200	1,350	1,510	16	45
32-----	---	450	690	830	980	1,130	1,290	1,450	1,620	16	40
33-----	---	480	740	890	1,050	1,211	1,380	1,560	1,730	17	49
34-----	---	---	800	950	1,120	1,290	1,480	1,670	1,860	17	30
35-----	---	---	860	1,010	1,180	1,380	1,570	1,790	1,990	18	22
36-----	---	---	920	1,070	1,250	1,460	1,680	1,910	2,140	18	17
37-----	---	---	---	1,130	1,320	1,550	1,780	2,040	2,290	19	24
38-----	---	---	---	1,190	1,390	1,640	1,890	2,170	2,450	19	11
39-----	---	---	---	1,250	1,460	1,730	2,000	2,300	2,600	20	16
40-----	---	---	---	1,310	1,540	1,820	2,120	2,430	2,760	20	15
41-----	---	---	---	---	1,610	1,910	2,240	2,570	2,930	21	6
42-----	---	---	---	---	1,680	2,000	2,360	2,720	3,100	21	3
43-----	---	---	---	---	1,750	2,090	2,470	2,860	3,270	22	3
44-----	---	---	---	---	1,830	2,180	2,590	3,010	3,450	22	2
											1,300

*Volume of trees as sawed out in average practice.

Correction factors for different species:

Chestnut, for diameters from 8 to 40 inches, subtract 10 percent.

Chestnut oak, for diameters from 32 to 40 inches, add 10 percent.

White oak, for diameters from 18 to 40 inches, add 10 percent.

Other common hardwoods, for all diameters, use the table without change.

*Table 18-9. Amount of Saw Timber in Softwood Trees (Pines, Spruces, etc.) of
Different Diameters and Merchantable Heights*

Diameter of tree, breast high (inches)	Number of 16-foot logs							Basis for this table (trees)
	1	2½	3	3½	4	4½	5	
	Volume * (board feet)							
8-----	37	52	66	75	84	----	----	12
9-----	41	58	70	82	93	----	----	9
10-----	47	66	77	92	100	120	----	12
11-----	53	74	86	100	120	140	----	13
12-----	60	83	97	120	140	160	200	8
13-----	68	94	110	130	160	190	220	4
14-----	77	110	120	150	180	210	240	7
15-----	--	120	140	170	200	240	270	11
16-----	--	130	160	190	230	270	310	20
17-----	--	150	180	220	260	300	340	21
18-----	--	170	210	250	280	330	380	20
19-----	--	190	230	280	320	370	420	34
20-----	--	210	260	310	360	410	470	27
21-----	--	---	290	350	400	460	520	33
22-----	--	---	320	390	440	510	570	40
23-----	--	---	360	430	490	560	620	37
24-----	--	---	400	470	540	620	680	37
25-----	--	---	440	520	600	680	740	47
26-----	--	---	480	560	660	740	810	52
27-----	--	---	---	600	720	800	880	43
28-----	--	---	---	650	780	870	950	45
29-----	--	---	---	---	840	940	1,030	39
30-----	--	---	---	---	910	1,010	1,100	47
31-----	--	---	---	---	---	1,080	1,180	40
32-----	--	---	---	---	---	1,150	1,260	44
33-----	--	---	---	---	---	1,230	1,340	39
34-----	--	---	---	---	---	---	1,420	36
35-----	--	---	---	---	---	---	1,500	34
36-----	--	---	---	---	---	---	1,580	29

* Volume of trees as sawed out in average practice.

Correction factors for different species:

Hemlock:

For diameters from 8 to 10 inches, add 10 percent.

For diameters from 11 to 20 inches, add 22 percent.

For diameters from 21 inches and up, add 20 percent.

Red spruce:

For diameters from 8 to 10 inches, add 5 percent.

For diameters from 11 inches and up, add 25 percent.

Short leaf pine:

For diameters from 10 inches and under, add 15 percent.

For diameters from 11 to 19 inches, add 25 percent.

For diameters from 20 to 23 inches, add 25 percent.

For diameters from 24 inches and over, add 40 percent.

White pine and other common conifers, for all diameters, use the table without change.

18-30. Additional Information

For detailed information on logging and sawmill operations refer to TM 5-342.

Section VII. LAND CLEARING

18-31. General

Land clearing is a construction operation con-

sisting of clearing a designated area of all trees, downed timber, brush, other vegetation, rubbish,

structures and obstacles, removing surface boulders and other material embedded in the ground, and disposing of all materials cleared.

18-32. Equipment and Operation

a. The best piece of equipment for clearing is a crawler dozer, especially for heavy clearing and on steep slopes. In light clearing (brush and small trees), however, wheeled dozers have been found very economical. The Rome K/G Clearing Blade is superior to a standard bulldozer blade for clearing operations. This blade comes in two sizes, a 4600-pound blade that fits the Allis-Chalmers HD-16M or Caterpillar D7E tractors and a 4000-pound blade that fits the airmobile D6B tractor. Graders can be used in stripping operations where the soil is free from root masses,

stumps, and boulders. Rooters (tractor-towed) can also be used to break roots and frozen material.

b. A dozer with the Rome K/G Blade attachment can clear about 2 acres per hour in light growth and 1 acre per hour in heavy growth. A dozer with a standard blade can clear small brush and trees at about 1,000 square yards per hour; medium trees (4-10 inches diameter), 2 to 9 minutes per tree; and large trees (10 inches plus diameter), 5 to 20 minutes per tree. Two tractors pulling a Navy anchor chain can clear 3 to 18 acres per hour in light to medium brush.

18-33. Detailed Information

TM 5-331 covers clearing operations in detail.

Section VIII. SNOW REMOVAL

18-34. General

The aim of snow removal and ice control is to permit the continuous maximum safe operational use of all facilities with the best possible running snow removal and ice control operation. It is vitally important that certain general preparations be made prior to the onset of winter.

18-35. General Preparations

The following is a list of preparations to be made prior to the winter season:

a. *Meteorological Liaison.* Proper cooperation with local and regional weather offices can result in adequate assessment of storm conditions prior to its arrival.

b. *Operation Priorities.* Establish priorities for plowing, routing of equipment, equipment to be used, widths to be cleared, snow storage and dump areas, and handling of anticipated special problems.

c. *Communication System.* A definite set of radio and signal control regulations must be established to insure coordination between the air traffic control officer and the snow removal teams working on airfields.

d. *Snow Markers.* In regions of heavy snowfall, markers are placed at drainage structures, curb ends, hydrants, switch targets, etc. to help avoid damage to the marked objects and equipment being used. These markers may be wooden stakes, planted trees, or dye.

e. Equipment Readiness.

(1) All vehicles and mechanical equipment utilized in any way with snow removal and ice control must be fully inspected, repaired, and reconditioned during the off-season.

(2) Arrangements must be made for use of heated space for servicing of equipment and heated storage to insure readiness of the equipment.

f. Snow and Ice Control Measures.

(1) Snow fences can be erected along traffic areas to control drifting snow.

(2) Ice control chemicals should be made available for employment against icing conditions. These chemicals include sodium chloride, calcium chloride, and chemical urea.

(3) Abrasives can be used to reduce slipping and skidding. These include cinders, sand, pea gravel, chert, coal, and sawdust.

18-36. Snow Removal Operations

a. When light dry snowfalls occur and high speed sweepers are available, removal operations should commence at the beginning of the snowfall and continue as necessary until snowfall ceases.

b. Where high speed sweepers are not available snow removal operations shall begin—

(1) When 2 inches of snow has fallen.

(2) Immediately after the snow has stopped falling, regardless of depth and if there is no indication of freezing rain.

(3) When drifting conditions make emergency operations hazardous.

c. Plow blades should be raised $\frac{1}{2}$ to 1 inch for plowing uneven surfaces and 2 or more inches for rough surfaces. Blades should be raised to prevent damage to railroad tracks, curbs or other low obstructions.

18-37. Sample Operation Priorities (Posts, Bases, etc.)

a. Priority 1.

- (1) Fire lanes.
- (2) Hospital and ambulance services.
- (3) POL areas.
- (4) Ammunition storage areas.
- (5) Telecommunication sites.
- (6) Important access roads.

b. Priority 2.

(1) Railroads and loading and unloading facilities.

(2) Roads and parking for places of employment.

c. Priority 3.

(1) Roads and parking areas for quarters, barracks blocks, messes, etc.

(2) Schools, PX's, and commissary.

(3) Roads and parking areas for recreation centers.

18-38. Sample Operation Priorities (Airfields)

a. Priority 1.

(1) Main or all-weather runway.

(2) Adjoining taxiways including those to any alert hangars.

(3) Apron access taxiways.

(4) Airfield crash truck lanes.

(5) Access roads to weapons and/or ammunition storage.

b. Priority 2.

(1) Secondary runways (using wind forecast for priority).

(2) Secondary taxiways.

(3) Aircraft operational areas such as aprons, hardstands, arming points, etc.

(4) Flying control access routes.

(5) Fire lanes.

(6) POL areas.

(7) Primary station roads including access roads to remote telecommunication sites.

c. Priority 3.

(1) All remaining runways and station roads.

(2) Parking areas at places of employment.

(3) Railroads including loading and unloading facilities.

(4) Parking areas at places of recreation.

(5) Any remaining sites.

18-39. Detailed Information

TM 5-624 discusses snow removal operations in detail.



APPENDIX A

REFERENCES

A-1. Army Regulations (AR)

55-650	Military Railroads.
117-5	Military Mapping and Geodesy.
310-25	Dictionary of United States Army Terms.
310-50	Authorized Abbreviations and Brevity Codes.
385-63	Regulations for Firing Ammunition for Training, Target Practice, and Combat.
420-47	Refuse Collection and Disposal.
700-68	Safe Handling, Storing, Shipping, Use, and Disposal of Compressed Gas Cylinders.
701-5	Materiel Management Responsibilities Federal Supply. Classification (FSC) Class Assignments.

A-2. Field Manuals (FM)

3-8	Chemical Reference Handbook.
3-12	Operational Aspects of Radiological Defense.
5-1	Engineer Troop Organization and Operations.
5-15	Field Fortifications.
5-20	Camouflage.
5-25	Explosives and Demolitions.
5-26	Employment of Atomic Demolition Munitions (ADM).
(C) 5-31	Boobytraps (U).
5-34	Engineer Field Data.
5-36	Route Reconnaissance and Classification.
6-2	Field Artillery Survey.
19-15	Civil Disturbances and Disasters.
20-10	Military Support of Civil Defense.
20-32	Landmine Warfare.
21-10	Military Sanitation.
21-26	Map Reading.
27-10	The Law of Land Warfare.
30-9	Military Intelligence Battalion, Field Army.
(S) 30-9A	Military Intelligence Battalion, Field Army (U).
30-10	Terrain Intelligence.
31-10	Denial Operations and Barriers.
55-15	Transportation Reference Data.
55-20	Army Rail Transport Operations.
100-10	Combat Service Support.
101-10-1	Staff Officer's Field Manual: Organizational, Technical and Logistical Data, Unclassified Data.
(S) 101-10-3	Staff Officer's Field Manual: Organizational, Technical, and Logistical Data, Classified Data (U).
(C) 101-20	United States Army Aviation Planning Manual (U).
101-31-1	Staff Officer's Field Manual: Nuclear Weapons Employment Doctrine and Procedures.

A-3. Technical Manuals (TM)

3-210	Fallout Prediction.
3-240	Field Behavior of Chemical, Biological and Radiological Agents.
5-200	Camouflage Materials.
5-210	Military Floating Bridge Equipment.
5-220	Passage of Obstacles Other Than Minefields.
5-232	Elements of Surveying.
5-233	Construction Surveying.
5-235	Special Surveys.
5-237	Surveying Computer's Manual.
5-241-1	Grids and Grid References.
5-243	Cartographic Aerial Photography.
5-245	Offset Photolithographic & Map Reproduction.
5-248	Foreign Maps.
5-258	Pile Construction.
5-270	Cableways, Tramways, and Suspension Bridges.
5-277	Bailey Bridge.
5-297	Well Drilling Operations.
5-301	Staff Tables of Engineer Functional Components System.
5-302	Construction in the Theater of Operations.
5-303	Bills of Materials and Equipment of the Engineer Functional Components System.
5-311	Military Protective Construction (Nuclear Warfare and Chemical and Biological Operations).
5-312	Military Fixed Bridges.
5-315	Firefighting and Rescue Procedures in Theaters of Operations.
5-330	Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations.
5-331	Series Utilization of Engineer Construction Equipment.
5-333	Construction Management.
5-337	Paving and Surfacing Operations.
5-342	Logging and Sawmill Operation.
5-343	Military Petroleum Pipeline Systems.
5-349	Arctic Construction.
5-351	Gas Generating.
5-360	Port Construction and Rehabilitation.
5-370	Railroad Construction.
5-371	I-Beam Railway Bridge.
5-372	Unit Construction Railway Bridge.
5-373	Through Truss Railway Bridges.
5-374	Light Standard and Standard Unit Steel Trestles.
5-441	Geodetic and Topographic Surveying.
5-442	Precise Astronomic Surveys.
5-443	Field Classification Surveys.
5-460	Carpentry and Building Construction.
5-503	Bills of Materials and Equipment of the Engineer Functional Components System.
5-624	Roads, Runways, and Miscellaneous Pavements: Repairs and Utilities.
5-634	Refuse Collection and Disposals: Repair and Utilities.
5-665	Operation of Sewerage and Sewerage Treatment Facilities at Fixed Army Installations.

5-666	Inspections and Preventive Maintenance Services, Sewage Treatment Plants and Sewer Systems at Fixed Installations.
5-680	Electrical Facilities, General Engineering, Data and Practices, Tools and Equipment, and Safety Practices, Repairs and Utilities.
5-681	Preventive Maintenance for Electrical Facilities.
5-687	Repairs and Utilities; Fire Protection Equipment and Appliances; Inspections, Operations and Preventive Maintenance.
5-700	Field Water Supply.
5-704	Construction Print Reading in the Field.
5-742	Concrete and Masonry.
5-744	Structural Steelwork.
5-760	Interior Wiring.
5-765	Electrical Power Transmission and Distribution.
5-766	Electric Power Generation in the Field.
5-809-1	Load Assumption for Buildings.
5-813 Series	Water Supply, Water Distribution Systems.
5-814 Series	Sewerage and Sewage Treatment.
9-1300-206	Care, Handling, Preservation and Destruction of Ammunition.
9-1300-214	Military Explosives.
9-1345-200	Land Mines.
9-1375-200	Demolition Materials.
9-1950	Rockets.
10-1100 Series	Petroleum Pipeline Operations.
19-500	Enemy Prisoners of War.
(C) 23-200	Capabilities of Nuclear Weapons (U).
30-245	Image Interpretation Handbook.
38-230	Preservation, Packaging, and Packing of Military Supplies and Equipment.

A-4. Technical Bulletin (TB)

5-360-1	Self-Elevating Barge.
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A-5. Supply Bulletin (SB)

38-100	Preservation, Packaging, Packing and Marking Materials, Supplies and Equipment Used by the Army.
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A-6. Graphic Training Aid (GTA)

5-2-1	Engineer Reconnaissance Card (1966).
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APPENDIX B

USEFUL FORMULAS AND TABLES

Section I. MATHEMATICAL DATA

B-1. Lengths, Areas, and Volumes

a. Legend.

- A = area
 a = altitude
 b = length of base
 c = hypotenuse
 C = circumference
 V = volume
 r = radius
 D = diameter
 $\pi = 3.1416$
 ℓ = length of arc
 k = length of chord

b. Formulas.

- (1) *Any triangle.* $A = \frac{1}{2}ab$
 (2) *Right triangle.* $a = \sqrt{c^2 - b^2}$
 $b = \sqrt{c^2 - a^2}$
 $c = \sqrt{a^2 + b^2}$
 (3) *Circle.* $A = \pi r^2$
 $A = 0.7854 D^2$ $C = \pi D$

(4) Segment of circle.

$$A = \frac{1}{2}[r(\ell - k) + ak]$$

$$\ell = \frac{\pi r}{180} \text{ (angle in degrees)}$$

$$k = 2\sqrt{2ar - a^2}$$

(5) Sector of circle.

$$A = \frac{r\ell}{2} = \frac{\pi r^2}{360} \text{ (angle in degrees)}$$

(6) *Regular polygons.* The area of any regular polygon (all sides equal, all angles equal) is equal to the product of the square of the length of one side and the factors shown in table B-1.

Example: Area of regular octagon having 6-inch sides is $6 \times 6 \times 4.828$ or 173.81 square inches.

- (7) *Rectangular and parallelogram.* $A = ab$
 (8) *Trapezoid.* $A = \frac{1}{2}a(b_1 + b_2)$

(9) *Irregular figures.* Measure widths at offsets regularly spaced along any straight line, and apply one of the following:

(a) *Trapezoidal rule.* $A = \frac{1}{2}$ interval between offsets X (sum of two end widths plus twice the sum of the intermediate widths).

Table B-1. Polygon Factors

Number of sides	Factor	Number of sides	Factor
3	0.433	8	4.828
4	1.000	9	6.182
5	1.720	10	7.694
6	2.598	11	9.366
7	3.634	12	11.196

(b) *Simpson's rule.* (Assumes lateral boundaries are parabolic curves.) $A = \frac{1}{3}$ interval between offsets X [sum of two end widths plus twice the sum of the odd widths except first and last (3d, 5th, 7th, etc.) plus 4 times the sum of the even widths (2d, 4th, 6th, etc.)].

Note. The rule requires an odd number of widths. If there is an even number, compute separately the area of a trapezoid at one end.

(10) *Cube.* $V = b^3$

(11) *Rectangular parallelepiped.* $V = ab_1b_2$

(12) *Prism or cylinder.* $V = aX$ (area of base)

(13) *Pyramid or cone.* $V = \frac{1}{3}aX$ (area of base)

(14) *Sphere.*

$$V = \frac{4}{3}\pi r^3 = \frac{\pi D^3}{6}$$

$$A = 4\pi r^2$$

(15) *Prismoidal section.*

$$V = \frac{1}{6} \text{ length } X \text{ (sum of end areas plus 4 times midsection area)}$$

B-2. Numerical Constants Containing π Table B-2. Numerical Constants Containing π

$\pi = 3.14159\ 26536$

$\log_{10}\pi = 0.49714\ 98727$

$10^{\pi} = 1.14472\ 98858$

	No.	Logarithm		No.	Logarithm
π	3.1415 927	0.4971 499	π^2	9.8696 044	0.9942 997
2π	6.2831 853	0.7981 799	$2\pi^2$	19.7392 088	1.2953 297
3π	9.4247 780	0.9742 711	$4\pi^2$	39.4784 176	1.5963 597
4π	12.5663 706	1.0992 099	$1/\pi^2$	0.1013 212	9.0057 003-10
8π	25.1327 412	1.4002 399	$1/(2\pi^2)$	0.0506 606	8.7046 703-10
$\pi/2$	1.5707 963	0.1961 199	$1/(4\pi^2)$	0.0253 303	8.4036 403-10
$\pi/3$	1.0471 976	0.0200 286	$\sqrt{\pi}$	1.7724 539	0.2485 749
$\pi/4$	0.7853 982	9.8950 899-10	$\sqrt{\pi/4}$ or $\sqrt{\pi}/2$	0.8862 269	9.9475 440-10
$\pi/6$	0.5235 988	9.7189 986-10	$\sqrt{\pi/4}$	0.4431 135	9.6465 149-10
$\pi/8$	0.3926 991	9.5940 599-10	$\sqrt{\pi}/2$	1.2533 141	0.0980 599
$2\pi/3$	2.0943 951	0.3210 586	$\sqrt{2/\pi}$	0.7978 846	9.9019 401-10
$4\pi/3$	4.1887 902	0.6220 886	π^3	31.0062 767	1.4914 496
$1/\pi$	0.3183 099	9.5028 501-10	$\sqrt[3]{\pi}$	1.4645 919	0.1657 166
$2/\pi$	0.6366 198	9.8038 801-10	$1/\sqrt[3]{\pi}$	0.6827 841	9.8342 834-10
$4/\pi$	1.2732 395	0.1049 101	$\sqrt[3]{\pi/2}$	2.1450 294	0.3314 332
$1/(2\pi)$	0.1591 549	9.2018 201-10	$1/\sqrt{\pi}$	0.5641 896	9.7514 251-10
$1/(4\pi)$	0.0795 775	8.9007 901-10	$2/\sqrt{\pi}$ or $\sqrt{4/\pi}$	1.1283 792	0.0524 551
$1/(6\pi)$	0.0530 516	8.7246 989-10			
$1/(8\pi)$	0.0397 887	8.5997 601-10			
$\pi/90$	0.0349 066	8.5429 075-10			
$\pi/180$	0.0261 799	8.4179 679-10			
$\pi/270$	0.0174 533	8.2418 776-10			
$\pi/360$	0.0087 266	7.9408 451-10			

B-3. Algebraic Formulas*a. Factors and Expansions.*

$$(a \pm b)^2 = a^2 \pm 2ab + b^2$$

$$(a \pm b)^3 = a^3 \pm 3a^2b + 3ab^2 + b^3$$

$$(a \pm b)^4 = a^4 \pm 4a^3b + 6a^2b^2 \pm 4ab^3 + b^4$$

$$a^2 + b^2 = (a - b)(a + b)$$

$$a^2 - b^2 = (a + b\sqrt{-1})(a - b\sqrt{-1})$$

$$a^3 - b^3 = (a - b)(a^2 + ab + b^2)$$

$$a^3 + b^3 = (a + b)(a^2 - ab + b^2)$$

$$a^4 + b^4 = (a^2 + ab\sqrt{2 + b^2})(a^2 - ab\sqrt{2 + b^2})$$

$$a^n - b^n = (a - b)(a^{n-1} +$$

$$a^{n-2}b + \dots + b^{n-1}), \text{ for odd values of } n.$$

$$a^n - b^n = (a + b)(a^{n-1} -$$

$$a^{n-2}b + \dots - b^{n-1}), \text{ for even values of } n.$$

b. Binomial Theorem. The expansion of $(a + b)^n$, where n is a positive integer is—

$$(a + b)^n = a^n + na^{n-1}b + \frac{n(n-1)}{2!}a^{n-2}b^2$$

$$+ \frac{n(n-1)(n-2)}{3!}a^{n-3}b^3 + \dots$$

$$+ \frac{n(n-1)(n-2)\dots(n-r+2)}{(r-1)!}a^{n-4+1}b^{r-1} + \dots + b^n.$$

c. Quadratic Equation. The roots of any quadratic equation when reduced to the form $ax^2 + bx + c \neq 0$ are

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

If $(b^2 - 4ac)$ is positive, the roots are real and unequal.If $(b^2 - 4ac)$ is zero, the roots are real and equal.If $(b^2 - 4ac)$ is negative, the roots are imaginary and unequal.If $(b^2 - 4ac)$ is a perfect square, the roots are rational and unequal.*d. Powers and Roots.*

$$a^x \cdot a^y = a^{(x+y)} \quad a^0 = 1 \text{ (if } a \neq 0)$$

$$(ab)^x = a^x b^x$$

$$\frac{a^x}{a^y} = a^{(x-y)} \quad a^{-x} = \frac{1}{a^x}$$

$$\left(\frac{a}{b}\right)^x = \frac{a^x}{b^x}$$

$$(a^x)^y = a^{xy} \quad a^{\frac{1}{x}} = \sqrt[x]{a}$$

$$\sqrt[x]{ab} = \sqrt[x]{a} \sqrt[x]{b}$$

$$\sqrt[x]{\sqrt[y]{a}} = \sqrt[xy]{a} \quad \frac{a^{\frac{x}{y}}}{a^{\frac{x}{z}}} = \sqrt[y]{a^{\frac{x}{z}}} \quad \sqrt[x]{\frac{a}{b}} = \frac{\sqrt[x]{a}}{\sqrt[x]{b}}$$

e. Proportion.

$$\text{If } \frac{a}{b} = \frac{c}{d}$$

$$\text{then } \frac{a+b}{b} = \frac{c+d}{d}, \quad \frac{a-b}{b} = \frac{c-d}{d},$$

$$\frac{a-d}{a+b} = \frac{c-d}{c+d}$$

*f. Logarithms.*If $a^b = x$,
then $\log_a x = b$, by definition.

For change of base, $\log_a x = \frac{\log_c x}{\log_c a}$

To any base, $\log MN = \log M + \log N$
 $\log M^A = A \log M$

$$\log \frac{M}{N} = \log MN^{-1} = \log M -$$

$$\log N \log \sqrt[n]{M} = \log M^{\frac{1}{n}} = \frac{1}{n}$$

$$\log M$$

g. Sums of Numbers.

The sum of the first n numbers,

$$\Sigma(n) = 1 + 2 + 3 + 4 + 5 + \dots + n =$$

$$n = \frac{n(n+1)}{2}$$

The sum of the squares of the first n numbers,

$$\Sigma(n^2) = 1^2 + 2^2 + 3^2 + 4^2 + 5^2 + \dots$$

$$n^2 = \frac{n(n+1)(2n+1)}{6}$$

The sum of the cubes of the first n numbers,

$$\Sigma(n^3) = 1^3 + 2^3 + 3^3 + 4^3 + 5^3 + \dots$$

$$+ n^3 = \frac{n^2(n+1)^2}{4}$$

h. Arithmetical Progression. If a is the first term; ℓ , the last term; d , the common difference; n , the number of terms; and s , the sum of n terms, then

$$\ell = a + (n-1)d \quad s = \frac{n}{2}(a + \ell)$$

$$s = \frac{n}{2} [2a + (n-1)d]$$

i. Geometrical Progression. If a is the first term; ℓ , the last term; r , the common ratio; n , the number of terms; and s , the sum of n terms, then

$$\ell = ar^{n-1} \quad s = a \frac{(1-r^n)}{1-r}$$

$$s = a \frac{(r^n - 1)}{r - 1} \quad s = \frac{\ell r - a}{r - 1}$$

If n becomes infinite and r less than unity:

$$s = \frac{a}{1-r}$$

j. Factorials. The symbol $n!$, called "n factorial", represents the product of the first n positive integers.

$$n! = 1.2.3 \dots n.$$

$$0! = 1, \text{ by definition.}$$

$$n! = e^{-n} n^n \sqrt{2\pi n}, \text{ approximately.}$$

k. Permutations. If P denotes the number of permutations of n things taken r at a time, then $P = n(n-1)(n-2) \dots (n-r+1)$

l. Combinations. If C denotes the number of combinations of n things taken r at a time, then

$$C = \frac{n(n-1)(n-2) \dots (n-r+1)}{r!}$$

$$C = \frac{n!}{r!(n-r)!}$$

Section II. PHYSICAL DATA

B-4. Equivalents of Measure

Equivalent lengths, areas, cubes, weights, pressures, densities, velocities, work measurements,

and U.S. weight equivalents are given in tables B-3 through B-11. Conversion scales for temperatures, lengths, and gallons are shown in figure B-1.

Table B-3. Lengths

Meters,* m	Inches, in.	Feet, ft.	Yard, yd.	Rods, r.	Chains, ch.	Miles, U.S.		Kilometers, km
						Statute	Nautical	
1	39.37	3.28083	1.09361	0.19884	0.04971	0. ³ 6214	0. ³ 5396	0.001
.02540	1	.08333	.02778	. ³ 5051	. ¹ 263	. ¹ 1578	. ¹ 1371	. ² 540
.30480	12	1	.33333	.06061	.01515	. ³ 1894	. ³ 1645	. ³ 048
.91440	36	3	1	.18182	.04545	. ⁵ 682	. ⁴ 934	. ⁹ 144
5.02921	198	16.5	5.5	1	.25	. ³ 125	. ² 714	. ⁵ 029
20.1168	792	66	22	22	1	.01250	.01085	.02012
1609.35	63360	5280	1760	320	80	1	.86839	1.60935
1853.25	72962.5	6080.20	2026.73	368.497	92.1243	1.15155	1	1.85325
1000	39370	3280.83	1093.61	198.838	49.7096	.62137	.53959	1

* 1 meter (m) = 10 decimeters (dm) = 100 centimeters (cm) = 1,000 millimeters (mm).

Note. Notations $\overset{2}{0}.\overset{3}{0}.\overset{4}{0}$ etc., indicate that the $\overset{2}{0}.\overset{3}{0}.\overset{4}{0}$ etc., are to be replaced by 2, 3, 4, etc., ciphers.

Example: 1 meter = $0.\overset{3}{0}6214 = 0.0006214$ statute miles.

Table B-4. Areas

Sq. meters, sq. m.	Sq. inches, sq. in.	Sq. feet, sq. ft.	Sq. yards, sq. yd.	Sq. rods, sq. r.	Acres, A	Hectares, ha	Sq. miles, Statute	Sq kilo- meters, sq. km
1	1550.00	10.7639	1.19599	0.03954	0.2471	0.0001	0.3861	0.1
.6452	1	.6944	.7716	.2551	.1594	.6452	.2491	.6452
.09290	144	1	.11111	.3673	.2296	.9290	.3587	.9290
.83613	1296	9	1	.03306	.2066	.8361	.3228	.8361
25.2930	39204	272.25	30.25	1	.00625	.2529	.9766	.2529
4046.87	6272640	43560	4840	160	1	.40469	.1563	.4047
10000	15499969	107639	11959.9	395.366	2.47104	1	.3861	.01
2589999	-----	27878400	3097600	102400	640	259.000	1	2.59000
1000000	-----	10763867	1195985	39536.6	247.104	100	.38610	1

Table B-5. Cubic Measures ¹

Cubic Deci- meters, dm or Liters	Cubic Inches, cu. in.	Cubic Feet, cu. ft.	Cubic Yards, cu. yd.	U.S. Quarts		U.S. Gallons		U.S. Bushels, bu.
				Liquid, 1 qt.	Dry d. qt.	Liquid, 1 gal.	Dry, d. gal.	
1	61.0234	0.3531	0.1308	1.05668	0.90808	0.26417	0.22702	0.02838
.01639	1	.5787	.2143	.01732	.01488	.4329	.3720	.4650
28.3170	1728	1	.03704	29.9221	25.7140	7.48055	6.42851	.80356
764.559	46656	27	1	807.896	694.279	201.974	173.570	21.6962
.94636	57.75	.03342	.1238	1	.85937	.25	.21484	.02686
1.10123	67.2006	.03889	.1440	1.16365	1	.29091	.25	.03125
3.78543	231	.13368	.4951	4	3.43747	1	.85937	.10742
4.40492	268.803	.15556	.5761	4.65460	4	1.16365	1	.125
35.2393	2150.42	1.24446	.04609	37.2368	32	9.30920	8	1

¹ See also table 18-8.

U.S. dry measure: 1 bushel=4 pecks=8 gallons=32 quarts=64 pints.

U.S. liquid measure: 1 gallon=4 quarts=8 pints=32 gills=128 fluid ounces. 1 U.S. gallon =0.83268 Imperial gallon.

Table B-6. Weights

Kilograms, kg	Grains, gr.	Ounces		Pounds		Tons		
		Troy, oz t.	Avoir., oz av.	Troy, lb t.	Avoir, lb av.	Net (short) 2000 lb.	Gross, (long), 2240 lb.	Metric 1000 kg
1	15432.4	32.1507	35.2740	2.67923	2.20462	0.1102	0.9842	0.001
.6480	1	.2083	.2286	.1736	.1429	.7143	.6378	.6480
.03110	480	1	1.09714	.08333	.06857	.3429	.3061	.3110
.02385	437.5	.91146	1	.07595	.06250	.3125	.2790	.2835
.37324	5760	12	13.1657	1	.82286	.4114	.3674	.3732
.45359	7000	14.5833	16	1.21528	1	.00050	.4464	.4536
907.185	14000000	29166.7	32000	2430.56	2000	1	.89286	.90719
1016.05	15680000	32666.7	35840	2722.22	2240	1.12	1	1.01605
1000	15432356	32150.7	35274.0	2679.23	2204.62	1.10231	.98421	1

1 long hundred weight (cwt.)=1/20 long ton=4 quarters=8 stone=112 lbs.=50.8024 kg.

Table B-7. Pressures

Kilograms per sq. centimeter kg/cm ²	Pounds per sq. inch, lb/in. ²	Pounds per sq foot, lb./ft. ²	Net tons, (2000 lbs.), per sq. foot	Atmospheres, Standard, 760 mm	Columns of mercury, (Hg), 13.69593 Sp. G.		Columns of water, max. density 4°C.	
					Millimeters	Inches	Meters	Feet
1	14.2234	2048.17	1.02408	0.96778	735.514	28.9572	10	32.8083
.07031	1	144	.07200	.06804	51.7116	2.03588	.70307	2.30665
.4882	.6944	1	.00050	.4725	.35911	.01414	.4882	.01602
.97648	13.8889	2000	1	.94502	718.216	28.2762	9.76482	32.0367
1.03329	14.6969	2116.35	1.05818	1	760	29.9212	10.3329	33.9006
.1360	.01934	2.78468	1.1392	.1316	1	.03937	.01360	.04461
.03453	.49119	70.7310	.03537	.03342	25.4001	1	.34534	1.13299
.10	1.42234	204.817	.10241	.09678	73.5514	2.89572	1	3.28083
.03048	.43353	62.4283	.031221	.02950	22.4185	.88262	.30480	1

Table B-8. Densities

Grams per cu. centimeter g/cm ³	Pounds per cu. inch lb./in. ³	Pounds per cu. foot lb./ft. ³	Pounds per cu. yard lb./yd. ³	Kilograms per cu. meter kg/m ³	Pounds per bushel, U.S.	Pounds per gallon, dry U.S.	Pounds per gallon, liquid, U.S.	Kilograms per hectoliter kg/hl
1	0.03613	62.4283	1685.56	1000	77.6893	9.71116	8.34545	100
27.6797	1	1728	46656	27679.7	2150.42	268.803	231	2767.97
.01602	.5787	1	27	16.0184	1.24446	.15556	.13368	1.60184
.5933	.2143	.03704	1	.59327	.04609	.5762	.4951	.05933
.001	.3613	.06243	1.68556	1	.07769	.9711	.8345	.10
.01287	.4650	.80356	21.6962	12.8718	1	.125	.10742	1.28718
.10297	.3720	6.42851	173.570	102.974	8	1	.85937	10.2974
.11983	.4329	7.48052	201.974	119.826	9.30920	1.16365	1	11.9826
.01	.3613	.62428	16.8557	10	.77689	.09711	.08345	1

Table B-10. Work Measurements

Kilogram-meters per second, kg-m/sec.	Foot-pounds per second, ft.-lb./sec.	Horsepower		Poncelet, 100 kg-m/sec.	Kilowatt, kw.	Watts, 10 ergs/sec.	Thermal units per Sec.	
		U.S., 550 ft.-lbs./sec.	Metric, 75 kg-m/sec.				B.T.U. B.T.U./sec.	Calorie, kg-cal/sec.
1	7.23300	0.01315	0.01333	0.01	0.9806	9.80597	0.9296	0.2342
.13826	1	.1818	.1843	.1383	.1356	1.35573	.1285	.3237
76.0404	550	1	1.01387	.76040	.74565	745.650	.70865	.17812
75	542.475	.98632	1	.75	.73545	735.448	.69718	.17569
100	723.300	1.31509	1.33333	1	.98060	980.597	.92957	.23425
101.979	737.612	1.3411	1.35972	1.01979	1	1000	.94796	.23888
.10198	.73761	.1341	.1360	.1020	.001	1	.9480	.2389
107.577	778.104	1.41474	1.43436	1.07577	1.05490	1054.90	1	.25200
426.900	3087.77	5.61412	5.69200	4.26900	4.18617	4186.17	3.96832	1

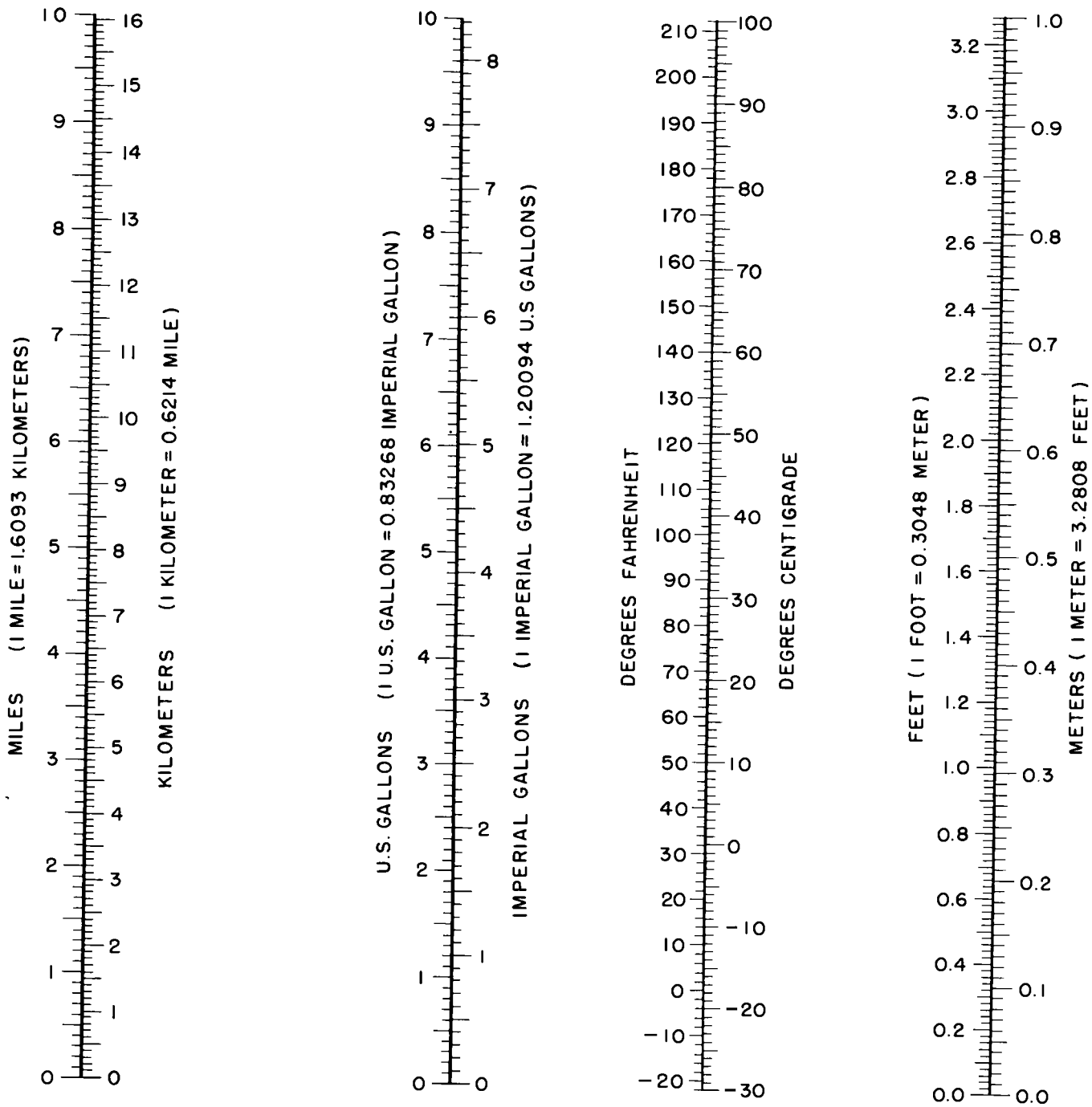


Figure B-1. Conversion scales.

B-5. Inches To Decimals of a Foot

Table B-9. Velocities

Meters per second (m./sec.)	Feet per second (ft./sec.)	Miles per hour (m.p.h.)	Nautical miles per hour (knots) (U.S.)	Kilometers per hour (km/hr.)
1	3.28083	2.23693	1.94254	3.6
.30480	1	.68182	.59209	1.09728
.44704	1.46667	1	.86839	1.60935
.51479	1.68894	1.15155	1	1.85325
.27778	.91134	.62137	.53959	1

Table B-11. United States Weight Equivalents

Avoirdupois pounds	Kilograms	Short tons	Long tons
1	0.453 59	0.005	0.000 446 43
2	.907 18	.0010	.000 892 86
3	1.360 78	.0015	.001 339 29
4	1.814 37	.0020	.001 785 71
5	2.267 96	.0025	.002 232 14
6	2.721 55	.0030	.002 678 57
7	3.175 15	.0035	.003 125 00

Table B-11. United States Weight Equivalents—Continued

Avoirdupois pounds	Kilograms	Short tons	Long tons	Avoirdupois pounds	Kilograms	Short tons	Long tons
8 -----	3.628 74	.0040	.003 571 43	10 000 -----	4535. 92	5	4.464 29
9 -----	4.082 33	.0045	.004 017 86	12 000 -----	5443. 11	6	5.357 14
2.204 62 -----	1	.001 102 31	.000 984 21	14 000 -----	6350. 29	7	6.250 00
4.409 24 -----	2	.002 204 62	.001 968 41	16 000 -----	7257. 48	8	7.142 86
6.613 87 -----	3	.003 306 93	.002 952 62	18 000 -----	8164. 66	9	8.035 71
8.818 49 -----	4	.004 409 24	.003 936 83	2240 -----	1016. 05	1.12	1
11.023 11 -----	5	.005 511 56	.004 921 03	4480 -----	2032. 09	2.24	2
13.227 73 -----	6	.006 613 87	.005 905 24	6720 -----	3048. 14	3.36	3
15.432 36 -----	7	.007 716 18	.006 889 44	8960 -----	4064. 19	4.48	4
17.636 98 -----	8	.008 818 49	.007 873 65	11 200 -----	5080. 24	5.60	5
19.841 60 -----	9	.009 920 80	.008 857 86	13 440 -----	6096. 28	6.72	6
2000 -----	907. 18	1	0.892 86	15 680 -----	7112. 32	7.84	7
4000 -----	1814. 37	2	1.785 71	17 920 -----	8128. 38	8.96	8
6000 -----	2721. 55	3	2.678 57	20 160 -----	9144. 42	10.08	9
8000 -----	3628. 74	4	3.571 43				

Table B-12. Inches to Decimals of a Foot

	0	1	2	3	4	5	6	7	8	9	10	11
0 -----	0	0.0833	0.1667	0.2500	0.3333	0.4167	0.5000	0.5833	0.6667	0.7500	0.8333	0.9167
1/16 -----	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1/8 -----	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271
3/16 -----	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
1/4 -----	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5/16 -----	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3/8 -----	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479
7/16 -----	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1/2 -----	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9/16 -----	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5/8 -----	.0512	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11/16 -----	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3/4 -----	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13/16 -----	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7/8 -----	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896
15/16 -----	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948

B-6. British Weight Markings

If British weights are marked with four separate figures in one line, the numbers represent long

tons of 2,240 pounds, hundred-weights of 112 pounds, stone of 14 pounds, and pounds. Thus 4-2-3-7 equals 9,233 pounds; 3-2-2 equals 366 pounds.

B-7. Foreign Weights and Measures

Table B-13. Foreign Weights and Measures

Denominations	Where used	American equivalents	Denominations	Where used	American equivalents
Almude -----	Portugal -----	4.422 gals.	Arshine -----	Russia -----	28 in.
Ardeb -----	Egypt -----	5.6188 bu.	Arshine (sq.) -----	Russia -----	5.44 sq. ft.
Are -----	Metric -----	0.02471 acre.	Artel -----	Morocco -----	1.12 lbs.
Arr't'l or li'ra -----	Portugal -----	1.0119 lbs.	Baril -----	Argentine Republic and Mexico.	20.077 gals.
Arroba -----	Argentine Republic.	25.32 lbs.	Barrel -----	Malta (customs) -----	11.2 gals.
Arroba -----	Brazil -----	32.38 lbs.	Berkovets -----	Russia -----	361.128 lbs.
Arroba -----	Cuba -----	25.36 lbs.	Bongkal -----	Fed. Malay States.	832 grains.
Arroba -----	Paraguay -----	25.32 lbs.	Bouw -----	Sumatra -----	7,096.5 sq. metrs.
Arroba -----	Venezuela -----	25.40 lbs.	Bu -----	Japan -----	0.12 inch.
Arroba (liquid) -----	Cuba, Spain and Venezuela.	4.263 gals.	Bushel -----	British Empire -----	1.03205 U.S. bu.

Table B-13. Foreign Weights and Measures—Continued

Denominations	Where used	American equivalents	Denominations	Where used	American equivalents
Caffiso	Malta	5.40 gals.	Hectolitre: Liquid	Metric	26.418 gals.
Candy	India (Bombay)	569 lbs.	Jarib	Persia (New)	2.471 acres.
Candy	India (Madras)	500 lbs.	Joch	Austria (Germany).	1.422 acres.
Cantar	Egypt	99.05 lbs.	Joch	Hungary	1.067 acres.
Cantar	Morocco	112 lbs.	Ken	Japan	5.97 feet.
Cantar	Turkey	124.45 lbs.	Kilogram kilo	Metric	2.2046 lbs.
Cantaro	Malta	175 lbs.	Kilometre	Metric	0.62137 mile.
Cast, Metric	Metric	3.086 grains.	Klafter	Austria (Germany).	2.074 yds.
Catty	China	1.333 $\frac{1}{3}$ lbs.	Koku	Japan	5.119 bu.
Catty	Japan	1.32 lbs.	Kwamme	Japan	8.2673 lbs.
Catty	Java, Malacca	1.36 lbs.	Last	Belgium, (Netherlands).	85.134 bu.
Catty	Thailand	2 $\frac{2}{3}$ lbs.	Last	England	82.56 bu.
Catty (stand)	Thailand	1.32 lbs.	Last	Germany	2 metric tons. (4,409+lbs.).
Catty	Sumatra	2.12 lbs.	Last	Prussia	112.29 bu.
Centaro	Central America	4.2631 gals.	Last	Scotland, Ireland.	82.564 bu.
Centner	Brunswick	117.5 lbs.	League (land)	Paraguay	4.633 acres.
Centner	Bremen	127.5 lbs.	Li	China	1,890 ft.
Centner	Denmark,	110.23 lbs.	Libra (lb.)	Argentina Republic.	1,0128 lbs.
	Norway.		Libra	Central America.	1.014 lbs.
Centner	Prussia	113.44 lbs.	Libra	Chile	1.014 lbs.
Centner	Sweden	93.7 lbs.	Libra	Cuba	1.0143 lbs.
Centner	Double or metric	220.46 lbs.	Libra	Mexico	1.01467 lbs.
Chetvert	Russia	5.957 bu.	Libra	Peru	1.0143 lbs.
Ch'ih	China	12.60 inches.	Libra	Uruguay	1.0143 lbs.
Ch'ih (metric)	China	1 meter.	Libra	Venezuela	1.0143 lbs.
Cho	Japan	2.451 acres.	Litre	Metric	1.0567 liq. qts.
Comb	England	4.1282 bu.	Litre	Metric	0.90810 dry qts.
Coyan	Thailand	2,645.5 lbs.	Livre (lb.)	Greece	1.1 lbs.
Cuadra	Argentina Republic.	4.2 acres.	Livre	Guiana (Dutch)	
Cuadra	Paraguay	94.70 yds.	Load, timber	England	50 cu. ft.
Cuadra (sq.)	Paraguay	1.85 acres.	Lumber (std.)	in Europe	165 cu. ft., or 1,980 ft. b. m.
Cuadra	Uruguay	1.82 acres.	Manzana	Nicaragua	1.742 acres.
Cubic meter	Metric	35.3 cu. ft.	Manzana	Costa Rica, Salvador.	1.727 acres.
Cwt. (hund. weight)	British	112 lbs.	Marc	Boliva	0.507 lb.
Dessiatine	Russia	2.6997 acres.	Maund	India	82 $\frac{2}{7}$ lbs.
Drachma (new)	Greece	15.43 gr., or 1 grm.	Metre	Metric	39.37 inches.
Fanega (dry)	Ecuador, Salvador.	1.5745 bu.	Mil	Denmark	4.68 miles.
Fanega	Chile	2.75268 bu.	Mil (geographic)	Denmark	4.61 miles.
Fanega	Guatemala,	1.53 bu.	Milla	Nicaragua	1.1594 miles.
Fanega	Spain.		Milla	Honduras	1.1493 miles.
Fanega	Mexico	2.57716 bu.	Mina (old)	Greece	2.202 lbs.
Fanega (double)	Uruguay	7.776 bu.	Morgen	Prussia	0.63 acre.
Fanega (single)	Uruguay	3.888 bu.	Oke	Egypt	2.8052 lbs.
Fanega	Venezuela	3.334 bu.	Oke (Ocque)	Greece	2.82 lbs.
Fanega (liquid)	Spain	16 gals.	Oke	Turkey	2.828 lbs.
Feddan	Egypt	1.04 acres.	Pic	Egypt	22.82 inches.
Frall (rais's)	Spain	50 lbs.	Picul	Borneo & Celebes.	135.64 lbs.
Frasco	Argentina Republic.	2.5098 liq. qts.	Picul	China	133 $\frac{1}{3}$ lbs.
Frasco	Mexico	2.5 liq. qts.	Picul	Java	136.16 lbs.
Frasila	Zanzibar	35 lbs.	Picul	Philippine Republic.	139.44 lbs.
Fuder	Luxemburg	264.18 gals.			
Funt	Russia	0.9028 lb.			
Gallon	British Empire	1.20094 U.S. gal.			
Garnice	Poland	1.0567 gal.			
Gram	Metric	15.432 grains.			
Hectare	Metric	2.471 acres.			
Hectolitre: Dry	Metric	2.838 bu.			

Table B-13. Foreign Weights and Measures—Continued

Denominations	Where used	American equivalents	Denominations	Where used	American equivalents
Pie	Argentine Republic.	0.94708 foot.	Tael Kuping	China	575.64 grs. (troy)
Pie	Spain	0.91416 foot.	Tan	Japan	0.25 acre.
Pik	Turkey	27.9 inches.	Tchvttert	Russia	5.96 bu.
Pood	Russia	36.113 lbs.	To	Japan	2.05 pecks.
Pund (lb)	Denmark	1.102 lbs	Ton	Space measure	40 cu. ft.
Quart	British Empire	1.20094 liq. qt.	Tonde cereals	Denmark	3.9480 bu.
Quart	British Empire	1.03205 dry qt.	Tonde Land	Denmark	1.36 acres.
Quarter	Great Britian	8.256 bu.	Tonne	France	2204.62 lbs.
Quintal	Argentine Republic.	101.28 lbs.	Tsubo	Japan	35.58 sq. ft.
Quintal	Brazil	120.54 lbs.	Tsun	China	1.26 inches.
Quintal	Castile, Peru	101.43 lbs.	Tunna (wheat)	Sweden	4.5 bu.
Quintal	Chile	101.41 lbs.	Tunnland	Sweden	1.22 acres.
Quintal	Mexico	101.47 lbs.	Vara	Argentine Republic.	34.0944 inches.
Quintal	Metric	220.46 lbs.	Vara	Costa Rica, Salvador.	32.913 inches.
Rottle	Israel	6.35 lbs.	Vara	Guatemala	32.909 inches
Sack (flour)	England	280 lbs.	Vara	Honduras	32.953 inches.
Sagene	Russia	7 feet.	Vara	Nicaragua	33.057 inches.
Salm	Malta	8.2 bu.	Vara	Chile and Peru	32.913 inches.
Se	Japan	0.02451 acre.	Vara	Cuba	33.386 inches.
Seer	India	2 2-35 lbs.	Vara	Mexico	32.992 inches.
Shaku	Japan	11.9303 inches.	Vedro	Russia	2.707 gals.
Sho	Japan	1.91 liq. quarts.	Verst	Russia	0.663 mile.
Skalpund	Sweden	0.937 lbs.	Vloka	Poland	41.50 acres.
Stone	British	14 lbs.	Wey	Scotland & Ireland.	41.282 bu.
Sun	Japan	1.193 inches.			

B-8. Properties of Materials*a. Weights and Specific Gravities of Certain Materials.*

Table B-14. Weights and Specific Gravities

Substance	Weight (pounds per cubic feet)	Specific gravity
BITUMINOUS SUBSTANCES:		
Asphaltum	81	1. 1-1. 5
Coal anthracite	97	1. 4-1. 7
Coal, bituminous	84	1. 2-1. 5
Coal, charcoal, pine	23	0. 28-0. 44
Coal, charcoal, oak	33	0. 47-0. 57
Coal, coke	75	1. 0-1. 4
Coal, lignite	78	1. 1-1. 4
Coal, peat, turf, dry	47	0. 65-0. 85
Graphite	131	1. 9-2. 3
Paraffin	56	0. 87-0. 91
Petroleum	54	0. 87
Petroleum, benzine	46	0. 73-0. 75
Petroleum, gasoline	42	0. 66-0. 69
Petroleum, refined	50	0. 79-0. 82
Pitch	69	1. 07-1. 15
Tar, bituminous	75	1. 20
BUILDING MATERIALS VARIOUS:		
Ashes, cinders	40-45	
Cement, portland, loose	90	
Cement, portland, set	183	2. 7-3. 2
Lime, gypsum, loose	53-64	
Mortar, set	103	1. 4-1. 9
Slags, bank screenings	98-117	

Table B-14. Weights and Specific Gravities—Continued

Substance	Weight (pounds per cubic feet)	Specific gravity
Slags, bank slag	67-72	
Slags, machine slag	96	
Slags, slag sand	49-55	
COAL AND COKE, PILED:		
Coal, anthracite	47-58	
Coal, bituminous, lignite	40-54	
Coal, charcoal	10-14	
Coal, coke	23-32	
Coal, peat, turf	20-26	
EARTH, ETC., EXCAVATED:		
Clay, damp, plastic	110	
Clay, dry	63	
Clay and gravel, dry	100	
Earth, dry, loose	76	
Earth, dry, packed	95	
Earth, moist, loose	78	
Earth, moist, packed	96	
Earth, mud, flowing	108	
Earth, mud, packed	115	
Riprap, limestone	80-85	
Riprap, sandstone	90	
Riprap, shale	105	
Sand, gravel, dry, loose	90-105	
Sand, gravel, dry packed	100-120	
Sand, gravel, dry, wet	118-120	
EXCAVATIONS IN WATER:		
Clay	80	
River mud	90	
Sand or gravel	60	
Sand or gravel and clay	65	
Soil	70	
Stone riprap	65	
LIQUIDS, VARIOUS:		
Alcohol, 100%	49	0. 79
Acid, muriatic, 40%	75	1. 20
Acid, nitric, 91%	94	1. 50
Acid, sulfuric, 87%	112	1. 80
Lye, soda, 66%	106	1. 70
Oils, mineral, lubricants	57	0. 90-0. 93
Oils, vegetable	58	0. 91-0. 94
Water, 4° C. (maximum density)	62. 428	1. 0
Water, 100° C	59. 830	0. 9584
Water, ice	56	0. 88-0. 92
Water, sea	64	1. 02-1. 03
Water, snow, fresh fallen	8	0. 125
MASONRY, ASHLAR:		
Granite, syenite, gneiss	165	2. 3-3. 0
Limestone, marble	160	2. 3-2. 8
Sandstone, bluestone	140	2. 1-2. 4
MASONRY, BRICK:		
Pressed brick	140	2. 2-2. 3
Common brick	120	1. 8-2. 0
Soft brick	100	1. 5-1. 7
MASONRY, CONCRETE:		
Cement, stone, sand	144	2. 2-2. 4
Cement, slag, etc	130	1. 9-2. 3
Cement, cinder, etc	100	1. 5-1. 7

Table B-14. Weights and Specific Gravities—Continued

Substance	Weight (pounds per cubic feet)	Specific gravity
MASONRY, DRY RUBBLE:		
Granite, syenite, gneiss	130	1. 9-2. 3
Limestone, marble	125	1. 9-2. 1
Sandstone, bluestone	110	1. 8-1. 9
MASONRY, MORTAR RUBBLE:		
Granite, syenite, gneiss	155	2. 2-2. 8
Limestone, marble	150	2. 2-2. 6
Sandstone, bluestone	130	2. 0-2. 2
METALS, ALLOYS, ORES:		
Aluminum, cast, hammered	165	2. 55-2. 75
Brass, cast, rolled	534	8. 4-8. 7
Bronze, 7.9 to 14% Sn	509	7. 4-8. 9
Bronze, aluminum	481	7. 7
Copper, cast, rolled	556	8. 8-9. 0
Copper ore, pyrites	262	4. 1-4. 3
Gold, cast, hammered	1205	19. 25-19. 3
Iron, cast, pig	450	7. 2
Iron, ferrosilicon	437	6. 7-7. 3
Iron, spiegeleiser	468	7. 5
Iron, wrought	485	7. 6-7. 9
Iron ore, hematite	325	5. 2
Iron ore, hematite in bank	160-180	-----
Iron ore, hematite loose	130-160	-----
Iron ore, limonite	237	3. 6-4. 0
Iron ore, magnetite	315	4. 9-5. 2
Iron slag	172	2. 5-3. 0
Lead	710	11. 37
Lead ore, galena	465	7. 3-7. 6
Magnesium, alloys	112	1. 74-1. 83
Manganese	475	7. 2-8. 0
Manganese ore, pyrolusite	259	3. 7-4. 6
Mercury	849	13. 6
Monel metal	556	8. 8-9. 0
Nickel	565	2. 9-9. 2
Platinum, cast, hammered	1330	21. 1-21. 5
Silver, cast, hammered	656	10. 4-10. 6
Steel, rolled	490	7. 85
Tin, cast, hammered	459	7. 2-7. 75
Tin ore, cassiterite	418	6. 4-7. 0
Zinc, cast, rolled	440	6. 9-7. 2
Zinc ore, blende	253	3. 9-4. 2
MINERALS:		
Asbestos	153	2. 1-2. 8
Barite	281	4. 50
Basalt	184	2. 7-3. 2
Bauxite	159	2. 55
Borax	109	1. 7-1. 8
Chalk	137	1. 8-2. 6
Clay, marl	137	1. 8-2. 6
Dolomite	181	2. 9
Feldspar, orthoclase	159	2. 5-2. 6
Gneiss, serpentine	159	2. 4-2. 7
Granite, syenite	175	2. 5-3. 1
Greenstone, trap	187	2. 8-3. 2
Gypsum, alabaster	159	2. 3-2. 8
Hornblende	187	3. 0
Limestone, marble	165	2. 5-2. 8
Magnesite	187	3. 0
Phosphate rock, apatite	200	3. 2

Table B-14. Weights and Specific Gravities—Continued

Substance	Weight (pounds per cubic feet)	Specific gravity
MINERALS—Continued		
Porphyry	172	2. 6-2. 9
Pumice, natural	40	0. 37-0. 90
Quartz, flint	165	2. 5-2. 8
Sandstone, bluestone	147	2. 2-2. 5
Shale, slate	175	2. 7-2. 9
Soapstone, talc	169	2. 6-2. 8
SOLIDS, VARIOUS:		
Cereals, barley (bulk)	39	-----
Cereals, corn, rye (bulk)	48	-----
Cereals, oats (bulk)	32	-----
Cereals, wheat (bulk)	48	-----
Cotton, flax, hemp	93	1. 47-1. 50
Fats	58	0. 90-0. 97
Flour, loose	28	0. 40-0. 50
Flour, pressed	47	0. 70-0. 80
Glass, common	156	2. 40-2. 60
Glass, crystal	184	2. 90-3. 00
Glass, plate or crown	161	2. 45-2. 72
Hay and straw (bales)	20	-----
Leather	59	0. 86-1. 02
Paper	58	0. 70-1. 15
Potatoes, piled	42	-----
Rubber, caoutchouc	59	0. 92-0. 96
Rubber goods	94	1. 0-2. 0
Salt, granulated, piled	48	-----
Saltpeter	67	-----
Starch	96	1. 53
Sulfur	125	1. 93-2. 07
Wool	82	1. 32
STONE, QUARRIED, PILED:		
Basalt, granite, gneiss	96	-----
Greenstone, hornblende	107	-----
Limestone, marble, quartz	96	-----
Sandstone	82	-----
Shale	92	-----
TIMBER, U.S. SEASONED:		
Moisture content by weight (seasoned timber 15 to 20%; green timber up to 50%):		
Ash, white, red	40	0. 62-0. 65
Cedar, white, red	22	0. 32-0. 38
Chestnut	41	0. 66
Cypress	30	0. 48
Elm, white	45	0. 72
Fir, Douglas Spruce	32	0. 51
Fir, eastern	25	0. 40
Hemlock	29	0. 42-0. 52
Hickory	49	0. 74-0. 84
Locust	46	0. 73
Maple, hard	43	0. 68
Maple, white	33	0. 53
Oak, chestnut	54	0. 86
Oak, live	59	0. 95
Oak, red, black	41	0. 65
Oak, white	46	0. 74
Pine, Oregon	32	0. 51
Pine, red	30	0. 48
Pine, white	26	0. 41
Pine, yellow, longleaf	44	0. 70

Table B-14. *Weights and Specific Gravities—Continued*

Substance	Weight (pounds per cubic feet)	Specific gravity
Pine, yellow, shortleaf	38	0. 61
Poplar	30	0. 48
Redwood, California	26	0. 42
Spruce, white, black	27	0. 40-0. 46
Walnut, black	38	0. 61
Walnut, white	26	0. 41

The specific gravities of solids and liquids refer to water at 4°C. and 760 mm. pressure. The weights per cubic foot are derived from average specific gravities, except where stated that weights are for bulk, heaped or loose material, etc.

b. *Weights of Certain Building Materials.*Table B-15. *Weights of Building Materials*

Material	Weight, pounds per square foot
CEILINGS:	
Gypsum ceiling block, 2" thick unplastered	10
Plaster, on the concrete	5
Plaster, ¾", and metal lath	8
Plaster, ¾", and wood lath	8
Plaster board, unplastered	3
Suspended, metal lath and plaster ..	10
FLOORS:	
Cement finish, per inch thick	12
Cinder concrete, per inch thick	9
Cinder concrete fill, per inch thick ..	5
Gypsum slab, per inch thick	5
Hardwood flooring, ¾" thick	4
Sheathing, white, red, or Oregon pine, spruce, or hemlock, ¾" thick	2 ½
Sheathing, yellow pine, 1" thick	4
Terrazzo, tile, mastic, linoleum, per inch thick, including base	12
Wood block, creosoted, 3" thick	15
PARTITIONS:	
Channel studs, metal lath, cement plaster, solid, 2" thick	20
Hollow clay tile, 2"	13
Hollow clay tile, 3"	16
Hollow clay tile, 4"	18
Hollow clay tile, 5"	20
Hollow clay tile, 6"	25
Hollow clay tile, 8"	30
Hollow clay tile, 10"	35
Plaster, ½", on gypsum block or clay tile (one side)	4

Material	Weight, pounds per square foot
Solid gypsum block, 2"	9 ½
Solid gypsum block, 3"	13
Steel partitions	4
Studs, 2" x 4" plaster board, ½" plaster both sides	18
Studs, 2" x 4" wood or metal lath, ¾" plaster both sides	18
ROOFS:	
Corrugated metal	(Par 15-4)
Ready roofing, 3 ply	1
Roofing felt, 3 ply and gravel	5 ½
Roofing felt, 5 ply and gravel	6 ½
Roofing felt, 3 ply and slag	5 ½
Roofing felt, 5 ply and slag	5 ½
Shingles, wood	2
Tile or slate	5-20
WALLS:	
Brick, 9" thick	84
Brick, 13" thick	121
Brick, 18" thick	168
Brick, 22" thick	205
Brick, 26" thick	243
Brick 4", tile backing 4"	60
Brick 4", tile backing 8"	75
Brick 8", tile backing 4"	100
Brick 9", tile backing 8"	115
Corrugated metal siding	(Par 15-4)
Limestone 4", brick 9"	140
Limestone 4", brick 13"	175
Limestone 4", tile 8"	90
Limestone 4", tile 12"	100
Wall tile, 6" thick	30
Wall tile, 8" thick	33
Wall tile, 10" thick	40
Wall tile, 12" thick	45
Windows, glass, frame, and sash	8

c. Strengths of Certain Materials.

Table B-16. Strengths of Materials, Metals and Alloys

Material	Stress in P _s per square inch					Modulus of elasticity (pounds per square inch)	Elongation percent
	Tension ultimate	Elastic limit	Compression ultimate	Bending ultimate	Shearing ultimate		
Aluminum, bars, sheets	24-28	12-14					
Aluminum, wire, annealed	20-35	14					
Brass, 50% Zn	31	17.9	117	33.5			5
Brass, cast, common	18-24	6	30	20	36	9,000,000	
Brass, wire, hard	80						
Brass, wire, annealed	50	16				14,000,000	
Bronze, aluminum 5 to 7½% Zn	75	40	120				
Bronze, Tobin, cast, 38% Zn	66						
Bronze, Tobin, rolled, 11½% Sn	80	40				14,500,000	
Bronze, Tobin, c. rolled 1/3% Pb	100						
Copper, plates, rods, bolts	32-35	10	32				
Iron, cast, gray	18-24			25-33			
Iron, cast, malleable	27-35	15-20	46	30	40		
Iron, wrought, shapes	48	26	Tensile	Tensile	5/8 tensile	28,000,000	
Steel, bridges, buildings, ships	60-72	33	Tensile	Tensile	¾ tensile	29,000,000	
Steel, cars	50-65	½ tensile	Tensile	Tensile	¾ tensile	29,000,000	
Steel, cast, hard	80	36	Tensile	Tensile	¾ tensile	29,000,000	¹ 17
Steel, cast, medium	70	31.5	Tensile	Tensile	¾ tensile	29,000,000	¹ 20
Steel, cast, soft	60	27	Tensile	Tensile	¾ tensile	29,000,000	¹ 24
Steel, locomotives, stationary boilers	55-65	½ tensile	Tensile	Tensile	¾ tensile	29,000,000	
Steel, plates for cold pressing	45-58	½ tensile	Tensile	Tensile	¾ tensile	29,000,000	
Steel, structural nickel (3.25% Ni)	85-100	50	Tensile	Tensile	¾ tensile	29,000,000	(2)
Steel, structural silicon	80-95	45	Tensile	Tensile	¾ tensile	29,000,000	
Steel wire, annealed	80	40					
Steel wire, bridge cable	215	95					
Steel wire, unannealed	120	60					

¹ 2" gage length.² 1,500,000 tensile strength—8" gage length.

Table B-17. Strengths of Materials, Building Materials

Material	Average ultimate stress (pounds per square inch)			Safe working stress (pounds per square inch)			Modulus of elasticity (pounds per square inch)
	Compression	Tension	Bending	Compression	Bearing	Shearing	
Masonry, brick, common	10,000	200	600				
Masonry, granite				420	600		
Masonry, limestone, bluestone				350	500		
Masonry, sandstone				280	400		
Masonry, rubble				140	250		
Ropes, cast steel hoisting		80,000					
Ropes, manila		8,000					
Ropes, standing, derrik		70,000					
Stone, bluestone	12,000	1,200	2,500	1,200	1,200	200	7,000,000
Stone, granite, gneiss	12,000	1,200	1,600	1,200	1,200	200	7,000,000
Stone, limestone, marble	8,000	800	1,500	800	800	150	7,000,000
Stone, sandstone	5,000	150	1,200	500	500	150	3,000,000
Stone, slate	10,000	3,000	5,000	1,000	1,000	175	14,000,000

d. *Coefficients of Expansion of Certain Materials.* The coefficient of linear expansion (ϵ) of a material is the change in length, per unit of length, for a change of 1 degree of temperature. The coefficient of surface expansion is approximately two times the linear coefficient, and the coefficient of volume expansion, for solids, is approximately three times the linear coefficient.

(1) A bar, free to move, will increase in length with an increase in temperature and will decrease in length with a decrease in temperature. The change in length will be $\epsilon t \ell$, where ϵ is the coefficient of linear expansion, t the change in temperature, and ℓ the length. If the ends of a bar are fixed, a change in temperature (t) will cause a change in the unit stress of $E\epsilon t$, and in the total stress of $A E \epsilon t$, where A is the cross sectional area of the bar and E the modulus of elasticity.

(2) Table B-18 gives the coefficient of linear

expansion for 100°, of 100 times the value indicated above.

Example: A piece of medium steel is exactly 40 feet long at 60° F. Find the length at 90° F. assuming the ends free to move.

$$\begin{aligned}\text{Change of length} &= \epsilon t \ell = \frac{.00067 \times 30 \times 40}{100} \\ &= .00804 \text{ foot.}\end{aligned}$$

(3) The length at 90° F. is 40.00804 feet.

Example: A piece of medium steel is exactly 40 feet long and the ends are fixed. If the temperature increases 30° F., what is the resulting change in the unit stress?

$$\begin{aligned}\text{Change in unit stress} &= E \epsilon t = \frac{29,000,000 \times 0.00067 \times 30}{100} \\ &= 5830 \text{ lb per sq in.}\end{aligned}$$

(4) The volumetric expansion of water, in relation to degrees centigrade change in temperature, is shown in table B-19.

Table B-18. Coefficients of Expansion of Materials for 100 Degrees = 100 ϵ

Materials	Linear expansion		Materials	Linear expansion	
	Centigrade	Fahrenheit		Centigrade	Fahrenheit
METALS AND ALLOYS:			METALS AND ALLOYS—Continued		
Aluminum, wrought	0.00231	0.00128	Steel, stainless, 18-8	.00178	.00099
Brass	.00188	.00104	Zinc, rolled	.00311	.00173
Bronze	.00181	.00101	STONE AND MASONRY:		
Copper	.00168	.00093	Ashlar masonry	.00063	.00035
Iron, cast, gray	.00106	.00059	Brick masonry	.00055	.00031
Iron, wrought	.00120	.00067	Cement, portland	.00107	.00059
Iron, wire	.00124	.00069	Concrete	.00143	.00079
Lead	.00286	.00159	Granite	.00084	.00047
Magnesium, various alloys	.0029	.0016	Limestone	.00080	.00044
Nickel	.00126	.00070	Marble	.00100	.00056
Steel, cast	.00110	.00061	Plaster	.00166	.00092
Steel, hard	.00132	.00073	Rubble masonry	.00063	.00035
Steel, medium	.00120	.00067	Sandstone	.00110	.00061
Steel, soft	.00110	.00061	Slate	.00104	.00058
TIMBER			TIMBER		
Fir	parallel to fiber	0.00037	Fir	perpendicular to fiber	0.0058
Maple		.00064	Maple		.0048
Oak		.00049	Oak		.0054
Pine		.00054	Pine		.0034
		0.00021			0.0032
		.00036			.0027
		.00027			.0030
		.00030			.0019

Table B-19. Expansion of Water

Maximum Density = 1

° C.	Volume	° C.	Volume	° C.	Volume	° C.	Volume
0	1.000126	20	1.001732	50	1.011877	80	1.029003
4	1.000000	30	1.004234	60	1.016954	90	1.035829
10	1.000257	40	1.007627	70	1.022384	100	1.043116

B-9. Density of Gases**B-10. Contents of Horizontal Tanks**

The cubic content of a horizontal cylindrical tank of circular or elliptical cross section is given by the formula—

$$C = \frac{\pi}{4} \left(\frac{d^2 \ell}{231} \right) = 0.0034 d^2 \ell$$

where C is the capacity in gallons and d and ℓ are, respectively, the diameter and the length in inches. For a tank partially filled with liquid, the volume of liquid as a percentage of the total capacity is related to the depth of liquid as a percentage of the total depth (diameter) as shown in table B-21. Use columns 1 and 1a if the percentage depth is 50 percent or less; columns 2 and 2a if greater than 50 percent.

Table B-20. Density of Gases

Gas	Weight		Specific gravity	
	Grams per liter	Pounds per cubic foot	Air=0	0=1
Air	1.2930	0.08072	1.0000	0.9048
Acetylene	1.1791	0.07361	0.9119	0.8251
Ammonia	0.7708	0.04812	0.5961	0.5394
Argon	1.7809	0.11118	1.3773	1.2462
Bromine	7.14	0.446	5.52	5.00
Butane	2.594	0.1619	2.006	1.815
Carbon dioxide	1.9768	0.12341	1.5289	1.3833
Carbon monoxide	1.2504	0.07806	0.9671	0.8750
Chlorine	3.221	0.2011	2.491	2.254
Cial gas	0.41-0.96	0.026-0.060	0.32-0.74	0.29-0.67
Cyanogen	2.323	0.1450	1.797	1.626
Ethane	1.3562	0.08467	1.0489	0.9490
Ethylene	1.2609	0.07872	0.9752	0.8823
Fluorine	1.70	0.106	1.31	1.19
Helium	0.1785	0.01115	0.1381	0.1249
Hydrobromic acid	3.616	0.2257	2.797	2.530
Hydrochloric acid	1.6398	0.10237	1.2682	1.1475
Hydrofluoric acid	0.922	0.0576	0.713	0.645
Hydrogen	0.08987	0.00561	0.06950	0.06229
Hydrogen sulfide	1.538	0.09602	1.189	1.076
Krypton	3.708	0.2315	2.868	2.595
Methane	0.7168	0.04475	0.5544	0.5016
Methyl chloride	2.304	0.1438	1.782	1.612
Methyl ether	2.110	0.1317	1.632	1.477
Neon	0.9002	0.05620	0.6962	0.6299
Nitrogen	1.2507	0.07808	0.9673	0.8752
Nitric oxide	1.3402	0.08367	1.0365	0.9378
Nitrous oxide	1.9777	0.12347	1.5296	1.3839
Oxygen	1.42905	0.08921	1.1052	1.0000
Propane	2.0196	0.12608	1.5620	1.4132
Steam at 100° C	0.598	0.0373	0.462	0.418
Sulphur dioxide	2.9266	0.18270	2.2634	2.0479
Xenon	5.851	0.3653	4.525	4.094

Notes. The gases in this table, or the elements of which they are composed, are the isotopes or mixtures of isotopes normally occurring in nature.

Table B-21. Capacities of Partially Filled Tanks

Percent of depth		Percent of capacity		Percent of depth		Percent of capacity	
1—filled	2—unfilled	1a—filled	2a unfilled	1—filled	2—unfilled	1a—filled	2a unfilled
1	99	0.20	99.80	8	92	3.74	96.26
2	98	0.50	99.50	9	91	4.45	95.55
3	97	0.90	99.10	10	90	5.20	94.80
4	96	1.34	98.66	11	89	5.98	94.02
5	95	1.87	98.13	12	88	6.80	93.20
6	94	2.45	97.55	13	87	7.64	92.36
7	93	3.07	96.93	14	86	8.50	91.50

Table B-21. Capacities of Partially Filled Tanks—Continued

Percent of depth		Percent of capacity		Percent of depth		Percent of capacity	
1—filled	2—unfilled	1a—filled	2a unfilled	1—filled	2—unfilled	1a—filled	2a unfilled
15	85	9.40	90.60	33	67	28.84	71.16
16	84	10.32	89.68	34	66	30.03	69.97
17	83	11.27	88.73	35	65	31.19	68.81
18	82	12.24	87.76	36	64	32.44	67.56
19	81	13.23	86.77	37	63	33.66	63.34
20	80	14.23	85.77	38	62	34.90	65.10
21	79	15.26	84.74	39	61	36.14	63.86
22	78	16.32	83.68	40	60	37.39	62.61
23	77	17.40	82.60	41	59	38.64	61.36
24	76	18.50	81.50	42	58	39.89	60.11
25	75	19.61	80.39	43	57	41.14	58.86
26	74	20.73	79.27	44	56	42.40	57.60
27	73	21.86	78.14	45	55	43.66	56.34
28	72	23.00	77.00	46	54	44.92	55.08
29	71	24.07	75.93	47	53	46.19	53.81
30	70	25.31	74.69	48	52	47.45	52.55
31	69	26.48	73.52	49	51	48.73	51.27
32	68	27.66	72.34	50	50	50.00	50.00

B-11. Volume of Piled Sand or Gravel

To obtain the capacity of a conical pile, enter figure B-2, on the horizontal line at the bottom with the height of the pile in feet. Proceed upward to the point where the proper curve intersects this vertical line. Proceed horizontally from this intersection to the column at the left and read capacity in tons. For example, a 24-foot-

high conical pile of gravel will hold 1,770 tons. (See arrow and dotted line on chart.) For a pile shaped as shown, add to the capacity of one conical pile the capacity of an A-shaped pile from the "scale in tons per linear foot of storage." For example (see arrow and dotted line) an A-shaped pile of sand 22 feet high holds 28.8 tons per linear foot.

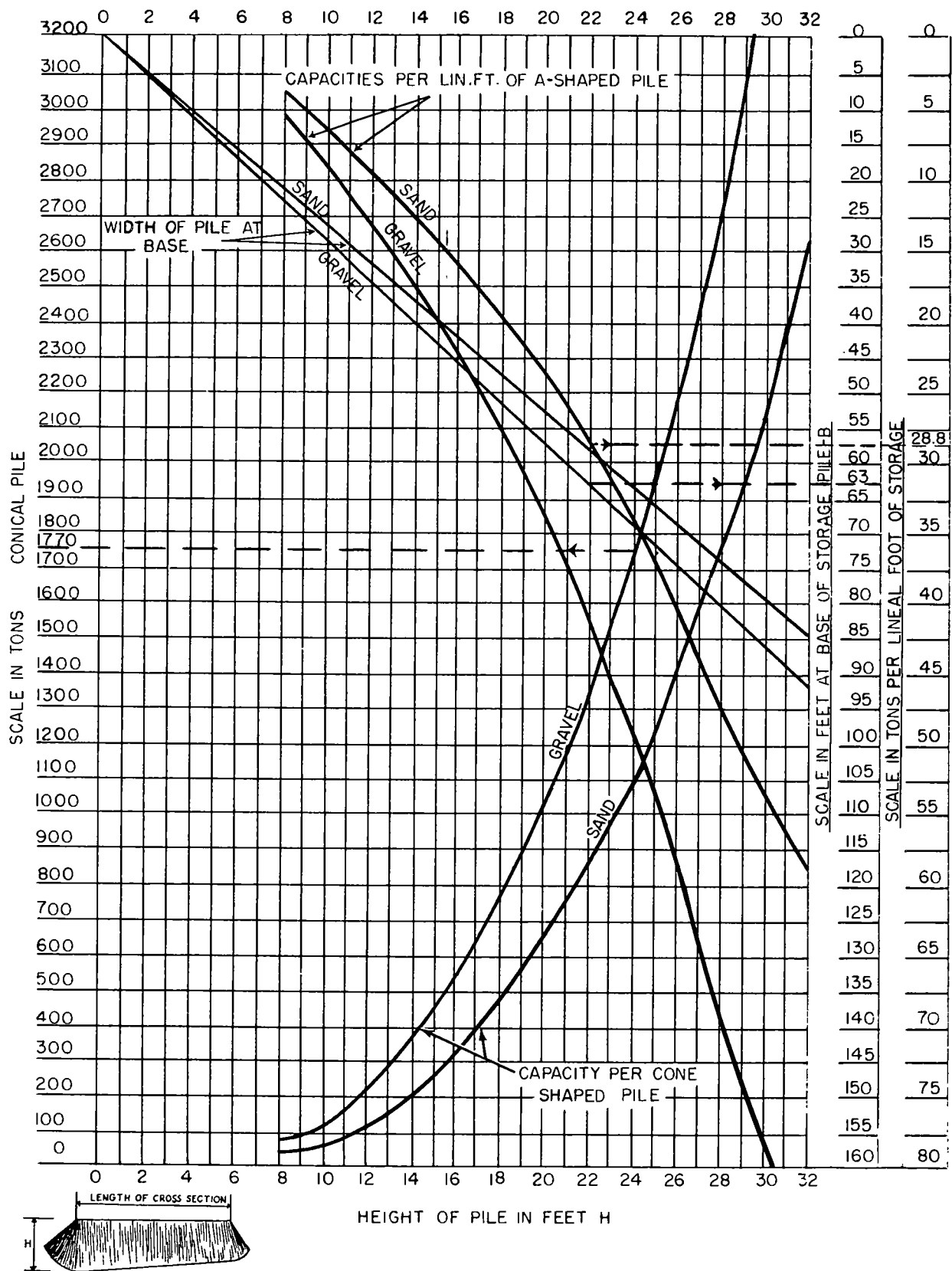


Figure B-2. Volume of piled sand or gravel.

B-12. Conversion Factors

Table B-22. Conversion Factors

Multiply—	by—	to obtain—
Acres	43,560	square feet.
acres	4,047	square meters.
acres	1.562×10^{-3}	square miles.
acres	5645.38	square varas.
acres	4,840	square yards.
acre-feet	43,560	cubic-feet.
acres	0.02471	acres.
acres	100	square meters.
atmospheres	76.0	cms. of mercury.
atmospheres	29.92	inches of mercury.
atmospheres	33.90	feet of water.
atmospheres	10,333	kgs. per square meter.
atmospheres	14.70	pounds per sq. inch.
atmospheres	1.058	tons per sq. foot.
Bars	9.870×10^{-1}	atmospheres.
bars	1	dynes per sq. cm.
bars	0.01020	kgs. per square meter
bars	2.089×10^{-3}	pounds per sq. foot.
bars	1.450×10^{-5}	pounds per sq. inch.
board-feet	144 sq. in. $\times$ 1 in.	cubic inches.
British thermal units	0.2520	kilogram-calories.
British thermal units	777.5	foot-pounds.
British thermal units	3.927×10^{-4}	horse-power-hours.
British thermal units	1.054	joules.
British thermal units	107.5	kilogram-meters.
British thermal units	2.928×10^{-4}	kilowatt-hours.
B.t.u. per min.	12.96	foot-pounds per sec.
B.t.u. per min.	0.02356	horse-power.
B.t.u. per min.	0.01757	kilowatts.
B.t.u. per min.	17.57	watts.
B. t.u. per sq. ft. per min	0.1220	watts per square inch.
bushels	1.244	cubic feet.
bushels	2,150	cubic inches.
bushels	0.03524	cubic meters.
bushels	4	pecks.
bushels	64	pints (dry).
bushels	32	quarts (dry).
Centares	1	square meters.
centigrams	0.01	grams.
centiliters	0.01	liters.
centimeters	0.3937	inches.
centimeters	0.01	meters.
centimeters	393.7	mils.
centimeters	10^{-5}	millimeters.
centimeters-dynes	7.233×10^{-5}	centimeter-grams.
centimeter-dynes	1.020×10^{-8}	meter-kilograms.
centimeter-dynes	7.376×10^{-8}	pound-feet.
centimeter-grams	980.7	centimeter-dynes.
centimeter-grams	10^{-3}	meter-kilograms.
centimeter-grams	7.233×10^{-3}	pound-feet.
centimeters of mercury	0.01316	atmospheres.
centimeters of mercury	0.4461	feet of water.
centimeters of mercury	136.0	kgs. per square meter.
centimeters of mercury	27.85	pounds per sq. foot.
centimeters of mercury	0.1934	pounds per sq. inch.
centimeters per second	1.969	feet per minute.
centimeters per second	0.03281	feet per second.
centimeters per second	0.036	kilometers per hour.
centimeters per second	0.6	meters per minute.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
centimeters per second	0.02237	miles per hour.
centimeters per second	3.728×10^{-4}	miles per minute.
cms. per sec. per sec	0.03281	feet per sec. per sec.
cms. per sec. per sec	0.036	kms. per hour per sec.
cms. per sec. per sec	0.02237	miles per hour per sec.
circular mils	5.067×10^{-6}	square centimeters.
circular mils	7.854×10^{-7}	square inches.
circular mils	0.7854	square mils.
cord-feet	4 ft. $\times$ 4 ft. $\times$ 1 ft.	cubic feet.
cords	8 ft. $\times$ 4 ft. $\times$ 4 ft.	cubic feet.
cubic centimeters	3.531×10^{-5}	cubic feet.
cubic centimeters	6.102×10^{-3}	cubic inches.
cubic centimeters	10^{-6}	cubic meters.
cubic centimeters	1.308×10^{-4}	cubic yards.
cubic centimeters	2.642×10^{-4}	gallons.
cubic centimeters	10^{-3}	liters.
cubic centimeters	2.113×10^{-3}	pints (liq.).
cubic centimeters	1.057×10^{-3}	quarts (liq.).
cubic feet	2.832×4	cubic cms.
cubic feet	1,728	cubic inches.
cubic feet	0.02832	cubic meters.
cubic feet	0.03704	cubic yards.
cubic feet	7.481	gallons.
cubic feet	28.38	liters.
cubic feet	59.84	pints (liq.).
cubic feet	29.92	quarts (liq.).
cubic feet per minute	472.0	cubic cms. per sec.
cubic feet per minute	0.1247	gallons per sec.
cubic feet per minute	0.4720	liters per second.
cubic feet per minute	62.4	lbs. of water per min.
cubic inches	16.39	cubic centimeters.
cubic inches	5.787×10^{-4}	cubic feet.
cubic inches	1.639×10^{-5}	cubic meters.
cubic inches	2.143×10^{-5}	cubic yards.
cubic inches	4.329×10^{-3}	gallons.
cubic inches	1.639×10^{-2}	liters.
cubic inches	0.03463	pints (liq.).
cubic inches	0.01732	quarts (liq.).
cubic meters	10^6	cubic centimeters.
cubic meters	35.31	cubic feet.
cubic meters	61,023	cubic inches.
cubic meters	1.308	cubic yards.
cubic meters	264.2	gallons.
cubic meters	10^3	liters.
cubic meters	2113	pints (liq.).
cubic meters	1057	quarts (liq.).
cubic yards	7.646×10^5	cubic centimeters.
cubic yards	27	cubic feet.
cubic yards	46,656	cubic inches.
cubic yards	0.7646	cubic meters.
cubic yards	202.0	gallons.
cubic yards	764.6	liters.
cubic yards	1616	pints (liq.).
cubic yards	807.9	quarts (liq.).
cubic yards per minute	0.45	cubic feet per second.
cubic yards per minute	3.367	gallons per second.
cubic yards per minute	12.74	liters per second.
Days	24	hours.
days	1440	minutes.
days	86,400	seconds.
decigrams	0.1	grams.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
deciliters	0.1	liters.
decimeters	0.1	meters.
degrees (angle)	60	minutes.
degrees (angle)	0.01745	radians.
degrees (angle)	3600	seconds.
degrees per second	0.01745	radians per second.
degrees per second	0.1667	revolutions per min.
degrees per second	0.002778	revolutions per sec.
dekagrams	10	grams.
dekaliters	10	liters.
dekameters	10	meters.
drams	1.772	grams.
drams	0.0625	ounces.
dynes	1.020×10^{-3}	grams.
dynes	7.233×10^{-8}	poundals.
dynes	2.248×10^{-6}	pounds.
dynes per square cm	1	bars.
Ergs	9.486×10^{-11}	British thermal units.
ergs	1	dyne-centimeters.
ergs	7.376×10^{-8}	foot-pounds.
ergs	1.020×10^{-3}	gram-centimeters.
ergs	10^{-7}	joules.
ergs	2.390×10^{-11}	kilogram-calories.
ergs	1.020×10^{-4}	kilogram-meters.
ergs per second	5.692×10^{-9}	B.t. units per minute.
ergs per second	4.426×10^{-4}	foot-pounds per minute.
ergs per second	7.376×10^{-8}	foot-pounds per second.
ergs per second	1.341×10^{-10}	horse-power.
ergs per second	1.434×10^{-9}	kg.-calories per minute.
ergs per second	10^{-10}	kilowatts.
Fathoms	6	feet.
feet	30.48	centimeters.
feet	12	inches.
feet	0.3048	meters.
feet	36	varas.
feet	$\frac{1}{3}$	yards.
feet of water	0.02950	atmospheres.
feet of water	0.8826	inches of mercury.
feet of water	304.8	kgs. per square meter.
feet of water	62.43	pounds per sq. ft.
feet of water	0.4335	pounds per sq. inch.
feet per minute	0.5080	centimeters per sec.
feet per minute	0.01667	feet per second.
feet per minute	0.01829	kilometers per hour.
feet per minute	0.3048	meters per minute.
feet per minute	0.01136	miles per hour.
feet per second	30.48	centimeters per sec.
feet per second	1.097	kilometers per hour.
feet per second	0.5921	knots per hour.
feet per second	18.29	meters per minute.
feet per second	0.6818	miles per hour.
feet per second	0.01136	miles per minute.
feet per 100 feet	1	per cent grade.
feet per sec. per sec	30.48	cms. per sec. per sec.
feet per sec. per sec	1.097	kms. per hr. per sec.
feet per sec. per sec	0.3048	meters per sec. per sec.
feet per sec. per sec	0.6818	miles per hr. per sec.
foot-pounds	1.268×10^{-3}	British thermal units.
foot-pounds	1.356×10^7	ergs.
foot-pounds	5.050×10^{-7}	horse-power-hours.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
foot-pounds	1.356	joules.
foot-pounds	3.241×10^{-4}	kilogram-calories.
foot-pounds	0.1383	kilogram-meters.
foot-pounds	3.766×10^{-7}	kilowatt-hours.
foot-pounds per minute	1.286×10^{-3}	B.t. units per minute.
foot-pounds per minute	0.01667	foot-pounds per sec.
foot-pounds per minute	3.030×10^{-5}	horse-power.
foot-pounds per minute	3.241×10^{-4}	kg./-calories per min.
foot-pounds per minute	2.260×10^{-5}	kilowatts.
foot-pounds per second	7.717×10^{-2}	B.t. units per minute.
foot-pounds per second	1.818×10^{-3}	horse-power.
foot-pounds per second	1.945×10^{-2}	kg.-calories per min.
foot-pounds per second	1.356×10^{-3}	kilowatts.
furlongs	40	rods.
Gallons	3785	cubic centimeters.
gallons	0.1337	cubic feet.
gallons	231	cubic inches.
gallons	3.785×10^{-3}	cubic meters.
gallons	4.951×10^{-3}	cubic yards.
gallons	3.785	liters.
gallons	8	pints (liq.).
gallons	4	quarts (liq.).
gallons per minute	2.228×10^{-3}	cubic feet per second.
gallons per minute	0.06308	liters per second.
gills	0.1182	liters.
gills	0.25	pints (liq.).
grains (troy)	1	grains (av.).
grains (troy)	0.06480	grams.
grains (troy)	0.04167	pennyweights (troy).
grams	980.7	dynes.
grams	15.43	grains (troy).
grams	10^{-3}	kilograms.
grams	10^3	milligrams.
grams	0.03527	ounces.
grams	0.03215	ounces (troy).
grams	0.07093	poundals.
grams	2.205×10^{-3}	pounds.
gram-calories	3.968×10^{-3}	British thermal units.
gram-centimeters	9.302×10^{-3}	British thermal units.
gram-centimeters	980.7	ergs.
gram-centimeters	7.233×10^{-3}	foot-pounds.
gram-centimeters	9.807×10^{-5}	joules.
gram-centimeters	2.344×10^{-8}	kilogram-calories.
gram-centimeters	10^{-5}	kilogram-meters.
grams per cm	5.600×10^{-3}	pounds per inch.
grams per cu. cm	62.43	pounds per cubic foot.
grams per cu. cm	0.3613	pounds per cubic inch.
grams per cu. cm	3.405×10^{-7}	pounds per mil-foot.
Hectares	2.471	acres.
hectares	1.076×10^6	square feet.
hectograms	100	grams.
hectoliters	100	liters.
hectometers	100	meters.
hectowatts	100	watts.
hemispheres (sol. angle)	0.5	sphere.
hemispheres (sol. angle)	4	spherical right angles.
hemispheres (sol. angle)	6.283	steradians.
horse-power	42.44	B.t. units per min.
horse-power	33,000	foot-pounds per min.
horse-power	550	foot-pounds per sec.
horse-power	1.014	horse-power (metric).

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
horse-power	10.70	kg.-calories per min.
horse-power	0.7457	kilowatts.
horse-power	745.7	watts.
horse-power (boiler)	33,520	B.t.u. per hour.
horse-power (boiler)	9.804	kilowatts.
horse-power-hours	2547	British thermal units.
horse-power-hours	1.98×10^6	foot-pounds.
horse-power-hours	2.684×10^6	joules.
horse-power-hours	641.7	kilogram-calories.
horse-power-hours	2.737×10^6	kilogram-meters.
horse-power-hours	0.7457	kilowatt-hours.
hours	60	minutes.
hours	3600	seconds.
Inches	2.540	centimeters.
inches	10^3	mils.
inches	.03	varas.
inches of mercury	0.03342	atmospheres.
inches of mercury	1.133	feet of water.
inches of mercury	345.3	kgs. per square meter.
inches of mercury	70.73	pounds per square ft.
inches of mercury	0.4912	pounds per square in.
inches of water	0.002458	atmospheres.
inches of water	0.07355	inches of mercury.
inches of water	25.40	kgs. per square meter.
inches of water	0.5781	ounces per square in.
inches of water	5.204	pounds per square ft.
inches of water	0.03613	pounds per square in.
Joules	9.486×10^{-4}	British thermal units.
joules	10^7	ergs.
joules	0.7376	foot-pounds.
joules	2.390×10^{-4}	kilogram-calories.
joules	0.1020	kilogram-meters.
joules	2.778×10^{-4}	watt-hours.
Kilograms	980,665	dynes.
kilograms	10^3	grams.
kilograms	70.93	poundals.
kilograms	2.2046	pounds.
kilograms	1.102×10^{-3}	tons (short).
kilogram-calories	3.968	British thermal units.
kilogram-calories	3088	foot-pounds.
kilogram-calories	1.588×10^{-3}	horse-power-hours.
kilogram-calories	4183	joules.
kilogram-calories	426.6	kilogram-meters.
kilogram-calories	1.162×10^{-3}	kilowatt-hours.
kg.-calories per min	51.43	foot-pounds per sec.
kg.-calories per min	0.09351	horse-power.
kg.-calories per min	0.06972	kilowatts.
kgs.cms. squared	2.373×10^{-3}	pounds-feet squared.
kgs.cms. squared	0.3417	pounds-inches squared.
kilogram-meters	9.302×10^{-3}	British thermal units.
kilogram-meters	9.807×10^7	ergs.
kilogram-meters	7.233	foot-pounds.
kilogram-meters	9.807	joules.
kilogram-meters	2.344×10^{-3}	kilogram-calories.
kilogram-meters	2.724×10^{-4}	kilowatt-hours.
kgs. per cubic meter	10^{-3}	grams per cubic cm.
kgs. per cubic meter	0.06243	pounds per cubic foot.
kgs. per cubic meter	3.613×10^{-5}	pounds per cubic inch.
kgs. per cubic meter	3.405×10^{-10}	pounds per mil. foot.
kgs. per meter	0.6720	pounds per foot.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
kgs. per square meter	9.678×10^{-5}	atmospheres.
kgs. per square meter	98.07	bars.
kgs. per square meter	3.281×10^{-3}	feet of water.
kgs. per square meter	2.896×10^{-3}	inches of mercury.
kgs. per square meter	0.2048	pounds per square ft.
kgs. per square meter	1.422×10^{-3}	pounds per square in.
kgs. per sq. millimeter	10^6	kgs. per square meter.
kilolines	10^3	maxwells.
kiloliters	10^3	liters.
kilometers	10^3	centimeters.
kilometers	3281	feet.
kilometers	10^3	meters.
kilometers	0.6214	miles.
kilometers	1093.6	yards.
kilometers per hour	27.78	centimeters per sec.
kilometers per hour	54.68	feet per minute.
kilometers per hour	0.9113	feet per second.
kilometers per hour	0.5396	knots per hour.
kilometers per hour	16.67	meters per minute.
kilometers per hour	0.6214	miles per hour.
kms. per hour per sec	27.78	cms. per sec. per sec.
kms. per hour per sec	0.9113	ft. per sec. per sec.
kms. per hour per sec	0.2778	meters per sec. per sec.
kms. per hour per sec	0.6214	miles per hr. per sec.
kilometers per min	60	kilometers per hour.
kilowatts	56.92	B.t. units per min.
kilowatts	4.425×10^4	foot-pounds per min.
kilowatts	737.6	foot-pounds per sec.
kilowatts	1.341	horse-power.
kilowatts	14.34	kg.-calories per min.
kilowatts	10^3	watts.
kilowatt-hours	3415	British thermal units.
kilowatt-hours	2.655×10^6	foot-pounds.
kilowatt-hours	1.341	horse-power-hours.
kilowatt-hours	3.6×10^4	joules.
kilowatt-hours	860.5	kilogram-calories.
kilowatt-hours	3.671×10^5	kilogram-meters.
knots	51.48	centimeters per sec.
knots	1.689	feet per second.
knots	1.853	kilometers per hour.
knots	1.152	miles per hour.
Links (engineer's)	12	inches.
links (surveyor's)	7.92	inches.
liters	10^3	cubic centimeters.
liters	0.03531	cubic feet.
liters	61.02	cubic inches.
liters	10^{-3}	cubic meters.
liters	1.308×10^{-3}	cubic yards.
liters	0.2642	gallons.
liters	2.113	pints (liq.).
liters	1.057	quarts (liq.).
liters per minute	5.885×10^{-4}	cubic feet per second.
liters per minute	4.403×10^{-3}	gallons per second.
$\log_{10} N$	2.303	$\log_e N$ or $\ln N$.
$\log_e N$ or $\ln N$	0.4343	$\log_{10} N$.
lumens per sq. ft.	1	foot-candles.
Meters	100	centimeters.
meters	3.2808	feet.
meters	39.37	inches.
meters	10^{-3}	kilometers.
meters	10^3	millimeters.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
meters	1.0936	yards.
meter-kilograms	9.807×10^7	centimeter-dynes.
meter-kilograms	10^3	centimeter-grams.
meter-kilograms	7.233	pound-feet.
meters per minute	1.667	centimeters per sec.
meters per minute	3.281	feet per minute.
meters per minute	0.05468	feet per second.
meters per minute	0.06	kilometers per hour.
meters per minute	0.03728	miles per hour.
meters per second	196.8	feet per minute.
meters per second	3.281	feet per second.
meters per second	3.6	kilometers per hour.
meters per second	0.06	kilometers per min.
meters per second	2.237	miles per hour.
meters per second	0.3728	miles per minute.
meters per sec. per sec	3.281	feet per sec. per sec.
meters per sec. per sec	3.6	kms. per hour per sec.
meters per sec. per sec	2.237	miles per hour per sec.
microns	10^{-6}	meters.
miles	1.609×10^3	centimeters.
miles	5280	feet.
miles	1.6093	kilometers.
miles	1760	yards.
miles	1900.8	varas.
miles per hour	44.70	centimeters per sec.
miles per hour	88	feet per minute.
miles per hour	1.467	feet per second.
miles per hour	1.6093	kilometers per hour.
miles per hour	0.8690	knots per hour.
miles per hour	26.82	meters per minute.
miles per hour per sec	44.70	cms. per sec. per sec.
miles per hour per sec	1.467	feet per sec. per sec.
miles per hour per sec	1.6093	kms. per hour per sec.
miles per hour per sec	0.4470	M. per sec. per sec.
miles per minute	2682	centimeters per sec.
miles per minute	88	feet per second.
miles per minute	1.6093	kilometers per min.
miles per minute	0.8684	knots per minute.
miles per minute	60	miles per hour.
milliers	10^3	kilograms.
milligrams	10^{-3}	grams.
milliliters	10^{-3}	liters.
millimeters	0.1	centimeters.
millimeters	0.03937	inches.
millimeters	39.37	mils.
mils.	0.002540	centimeters.
mils.	10^{-3}	inches.
miner's inches	1.5	cubic feet per min.
minutes (angle)	2.909×10^{-4}	radians.
minutes (angle)	60	seconds (angle).
months	30.42	days.
months	730	hours.
months	43,800	minutes.
months	2.628×10^6	seconds.
myriagrams	10	kilograms.
myriameters	10	kilometers.
myriawatts	10	kilowatts.
Nautical miles	6067	feet.
nautical miles	1.852	kilometers.
nautical miles	1.151	miles.
nautical miles	2025	yards.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
Ounces	8	drams.
ounces	437.5	grains.
ounces	28.35	grams.
ounces	0.0625	pounds.
ounces (fluid)	1.805	cubic inches.
ounces (fluid)	0.02957	liters.
ounces (troy)	480	grains (troy).
ounces (troy)	31.10	grams.
ounces (troy)	20	pennyweights (troy).
ounces (troy)	0.08333	pounds (troy).
ounces per square inch	0.0625	pounds per sq. inch.
Pennyweights (troy)	24	grains (troy).
pennyweights (troy)	1.555	grams.
pennyweights (troy)	0.05	ounces (troy).
perches (masonry)	24.75	cubic feet.
pints (dry)	33.60	cubic inches.
pints (liq.)	28.87	cubic inches.
poundals	13,826	dynes.
poundals	14.10	grams.
poundals	0.03108	pounds.
pounds	444,823	dynes.
pounds	7000	grains.
pounds	453.6	grams.
pounds	16	ounces.
pounds	32.17	poundals.
pounds (troy)	0.8229	pounds (av.).
pound-feet	1.356×10^7	centimeter-dynes.
pound-feet	13,825	centimeter-grams.
pound-feet	0.1383	meter-kilograms.
pound-feet squared	421.3	kgs.-cms. squared.
pounds-feet squared	144	pounds-ins. squared.
pounds-inches squared	2.926	kgs.-cms. squared.
pounds-inches squared	6.945×10^{-3}	pounds-feet squared.
pounds of water	0.01602	cubic feet.
pounds of water	27.68	cubic inches.
pounds of water	0.1198	gallons.
pounds of water per min.	2.669×10^{-4}	cubic feet per sec.
pounds per cubic foot	0.01602	grams per cubic cm.
pounds per cubic foot	16.02	kgs. per cubic meter.
pounds per cubic foot	5.787×10^{-4}	pounds per cubic inch.
pounds per cubic foot	5.456×10^{-9}	pounds per mil foot.
pounds per cubic inch	27.68	pounds per cubic cm.
pounds per cubic inch	2.768×10^4	kgs. per cubic meter.
pounds per cubic inch	1728	pounds per cubic foot.
pounds per cubic inch	9.425×10^{-4}	pounds per mil foot.
pounds per foot	1.488	kgs. per meter.
pounds per inch	178.6	grams per cm.
pounds per mil foot	2.306×10^6	grams per cubic cm.
pounds per square foot	0.01602	feet of water.
pounds per square foot	4.882	kgs. per square meter.
pounds per square foot	6.944×10^{-3}	pounds per sq. inch.
pounds per square inch	0.06804	atmospheres.
pounds per square inch	2.307	feet of water.
pounds per square inch	2.036	inches of mercury.
pounds per square inch	703.1	kgs. per square meter.
pounds per square inch	144	pounds per sq. foot.
Quadrants (angle)	90	degrees.
quadrants (angle)	5400	minutes.
quadrants (angle)	1.571	radians.
quarts (dry)	67.20	cubic inches.
quarts (liq.)	57.75	cubic inches.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
quintals	100	pounds.
quires	25	sheets.
Radians	57.30	degrees.
radians	3438	minutes.
radians	0.637	quadrants.
radians per second	57.30	degrees per second.
radians per second	0.1592	revolutions per sec.
radians per second	9.549	revolutions per min.
radians per sec. per sec	573.0	revs. per min. per min.
radians per sec. per sec	9.549	revs. per min. per sec.
radians per sec. per sec	0.1592	revs. per sec. per sec.
reams	500	sheets.
revolutions	360	degrees.
revolutions	4	quadrants.
revolutions	6.283	radians.
revolutions per minute	6	degrees per second.
revolutions per minute	0.1047	radians per second.
revolutions per minute	0.01667	revolutions per sec.
revs. per min. per min	1.745×10^{-3}	rads. per sec. per sec.
revs. per min. per min	0.01667	revs. per min. per sec.
revs. per min. per min	2.778×10^{-4}	revs. per sec. per sec.
revolutions per second	360	degrees per second.
revolutions per second	6.283	radians per second.
revolutions per second	60	revs. per minute.
revs. per sec. per sec	6.283	rads. per sec. per sec.
revs. per sec. per sec	3600	revs. per min. per min.
revs. per sec. per sec	60	revs. per min. per sec.
rods	16.5	feet.
Seconds (angle)	4.848×10^{-6}	radians.
spheres (solid angle)	12.57	steradians.
spherical right angles	0.25	hemispheres.
spherical right angles	0.125	spheres.
spherical right angles	1.571	steradians.
square centimeters	1.973×10^5	circular mils.
square centimeters	1.076×10^{-3}	square feet.
square centimeters	0.1550	square inches.
square centimeters	10^{-6}	square meters.
square centimeters	100	square millimeters.
square feet	2.296×10^{-5}	acres.
square feet	929.0	square centimeters.
square feet	144	square inches.
square feet	0.09290	square meters.
square feet	3.587×10^{-8}	square miles.
square feet	.1296	square varas.
square feet	1/9	square yards.
sq. feet-feet sqd	2.074×10^4	sq. inches-inches sqd.
square inches	1.273×10^6	circular mils.
square inches	6.452	square centimeters.
square inches	6.944×10^{-3}	square feet.
square inches	10^6	square mils.
square inches	645.2	square millimeters.
sq. inches-inches sqd	41.62	sq. cms.-cms. sqd.
sq. inches-inches sqd	4.823×10^{-5}	sq. feet-feet sqd.
square kilometers	247.1	acres.
square kilometers	10.76×10^6	square feet.
square kilometers	10^6	square meters.
square kilometers	0.3861	square miles.
square kilometers	1.196×10^6	square yards.
square meters	2.471×10^{-4}	acres.
square meters	10.764	square feet.
square meters	3.861×10^{-7}	square miles.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
square meters	1.196	square yards.
square miles	640	acres.
square miles	27.88×10^6	square feet.
square miles	2.590	square kilometers.
square miles	3.613,040.45	square yards.
square miles	3.098×10^6	square yards.
square millimeters	1.973×10^3	circular mils.
square millimeters	0.01	square centimeters.
square millimeters	1.550×10^{-3}	square inches.
square mils	1.273	circular mils.
square mils	6.452×10^{-6}	square centimeters.
square mils	10^{-6}	square inches.
square varas	.0001771	acres.
square varas	7.716049	square feet.
square varas	.0000002765	square miles.
square varas	.857339	square yards.
square yards	2.066×10^{-4}	acres.
square yards	9	square feet.
square yards	0.8361	square meters.
square yards	3.228×10^{-7}	square miles.
square yards	1.1664	square varas.
steradians	0.1592	hemispheres.
steradians	0.07958	spheres.
steradians	0.6366	spherical right angles.
steres	10^3	liters.
Temp. (deg. C.) +273	1	abs. temp. (deg. C.).
temp. (deg. C.) +17.8	1.8	temp. (deg. Fahr.).
temp. (deg. F.) +460	1	abs. temp. (deg. F.).
temp. (deg. F.) -32	$5/9$	temp. (deg. Cent.).
tons (long)	1016	kilograms.
tons (long)	2240	pounds.
tons (metric)	10^3	kilograms.
tons (metric)	2205	pounds.
tons (short)	907.2	kilograms.
tons (short)	2000	pounds.
tons (short) per sq. ft	9765	kgs. per square meter.
tons (short) per sq. ft	13.89	pounds per sq. inch.
tons (short) per sq. in	1.406×10^6	kgs. per square meter.
tons (short) per sq. in	2000	pounds per sq. inch.
Varas	2.7777	feet.
varas	33.3333	inches.
varas	.000526	miles.
varas	.9259	yards.
Watts	0.05692	B.t. units per min.
watts	10^7	ergs per second.
watts	44.26	foot-pounds per min.
watts	0.7376	foot-pounds per sec.
watts	1.341×10^{-3}	horse-power.
watts	0.01434	kg.-calories per min.
watts	10^3	kilowatts.
watt-hours	3.415	British thermal units.
watt-hours	2655	foot-pounds.
watt-hours	1.341×10^{-3}	horse-power-hours.
watt-hours	0.8605	kilogram-calories.
watt-hours	367.1	kilogram-meters.
watt-hours	10^{-3}	kilowatt-hours.
webers	10^9	maxwells.
weeks	168	hours.
weeks	10,080	minutes.
weeks	604,800	seconds.

Table B-22. Conversion Factors—Continued

Multiply—	by—	to obtain—
Yards -----	91.44	centimeters.
yards -----	3	feet.
yards -----	36	inches.
yards -----	0.9144	meters.
yards -----	1.08	varas.
years (common) -----	365	days.
years (common) -----	8760	hours.
years (leap) -----	366	days.
years (leap) -----	8784	hours.

B-13. Twenty-Year Calendar

	JAN 31 days	FEB 28 days	MAR 31 days	APR 30 days	MAY 31 days	JUNE 30 days	JULY 31 days	AUG 31 days	SEPT 30 days	OCT 31 days	NOV 30 days	DEC 31 days
1965	F	B	B	E	G	C	F	A	D	F	B	D
1966	G	C	C	F	A	D	F	B	E	G	C	E
1967	A	D	D	G	B	E	G	C	F	A	D	F
1968	B	E*	F	B	D	G	B	E	A	C	F	A
1969	D	G	G	C	E	A	C	F	B	D	G	B
1970	E	A	A	D	F	B	D	G	C	E	A	C
1971	F	B	B	E	G	C	E	A	D	F	B	D
1972	G	C*	D	G	B	E	G	C	F	A	D	F
1973	B	E	E	A	C	F	A	D	G	B	E	G
1974	C	F	F	B	D	G	B	E	A	C	F	A
1975	D	G	G	C	E	A	C	F	B	D	G	B
1976	E	A*	B	E	G	C	E	A	D	F	B	D
1977	G	C	C	F	A	D	F	B	E	G	C	E
1978	A	D	D	G	B	E	G	C	F	A	D	F
1979	B	E	E	A	C	F	A	D	G	B	E	G
1980	C	F*	G	C	E	A	C	F	B	D	G	B
1981	E	A	A	D	F	B	D	G	C	E	A	C
1982	F	B	B	E	G	C	E	A	D	F	B	D
1983	G	C	D	G	B	E	G	C	F	A	D	F
1984	B	E*	E	A	C	F	A	D	G	B	E	G

* Leap Years February has 29 days

CALENDAR (A)						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

CALENDAR (B)						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

CALENDAR (C)						
S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

CALENDAR (D)						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

CALENDAR (E)						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

CALENDAR (F)						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

CALENDAR (G)						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Figure B-3. Twenty-year calendar.

B-14. Table of Days Between Two Dates

Table B-23 shows the elapsed time in days be-

tween two dates, inclusive of both the initial and terminal date. For a leap year add 1 day after 28 February.

Table B-23. Elapsed Days

Day	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29	-----	88	119	149	180	210	241	272	302	333	363
30	30	-----	89	120	150	181	211	242	273	303	334	364
31	31	-----	90	-----	151	-----	212	243	-----	304	-----	365

Table B-23. Elapsed Days—Continued

Day	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	366	397	425	456	486	517	547	578	609	639	670	700
2	367	398	426	457	487	518	548	579	610	640	671	701
3	368	399	427	458	488	519	549	580	611	641	672	702
4	369	400	428	459	489	520	550	581	612	642	673	703
5	370	401	429	460	490	521	551	582	613	643	674	704
6	371	402	430	461	491	522	552	583	614	644	675	705
7	372	403	431	462	492	523	553	584	615	645	676	706
8	373	404	432	463	493	524	554	585	616	646	677	707
9	374	405	433	464	494	525	555	586	617	647	678	708
10	375	406	434	465	495	526	556	587	618	648	679	709
11	376	407	435	466	496	527	557	588	619	649	680	710
12	377	408	436	467	497	528	558	589	620	650	681	711
13	378	409	437	468	498	529	559	590	621	651	682	712
14	379	410	438	469	499	530	560	591	622	652	683	713
15	380	411	439	470	500	531	561	592	623	653	684	714
16	381	412	440	471	501	532	562	593	624	654	685	715
17	382	413	441	472	502	533	563	594	625	655	686	716
18	383	414	442	473	503	534	564	595	626	656	687	717
19	384	415	443	474	504	535	565	596	627	657	688	718
20	385	416	444	475	505	536	566	597	628	658	689	719
21	386	417	445	476	506	537	567	598	629	659	690	720
22	387	418	446	477	507	538	568	599	630	660	691	721
23	388	419	447	478	508	539	569	600	631	661	692	722
24	389	420	448	479	509	540	570	601	632	662	693	723
25	390	421	449	480	510	541	571	602	633	663	694	724
26	391	422	450	481	511	542	572	603	634	664	695	725
27	392	423	451	482	512	543	573	604	635	665	696	726
28	393	424	452	483	513	544	574	605	636	667	697	727
29	394	-----	453	484	514	545	575	606	637	666	698	728
30	395	-----	454	485	515	546	576	607	638	668	699	729
31	396	-----	455	-----	516	-----	577	608	-----	669	-----	730

B-15. Hours of Daylight

Table B-24. Hours of Daylight¹

Latitude north ²	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0°	12	12	12	12	12	12	12	12	12	12	12	12
10°	12	12	12	12	13	13	13	12	12	12	12	12
20°	11	12	12	13	13	13	13	13	12	12	11	11
30°	10	11	12	13	14	14	14	13	12	11	11	10
40°	10	11	12	13	14	15	15	14	12	11	10	9
50°	9	10	12	14	15	16	16	14	12	11	9	8
60°	7	9	12	15	17	19	18	16	12	10	8	6
70°	0	7	12	16	23	24	24	18	12	9	4	0
80°	0	0	12	24	24	24	24	24	12	5	0	0

¹ Time between sunrise and sunset. Approximately 30 minutes twilight is available before sunrise and after sunset.² For latitude south, subtract figures given from 24

B-16. Library Reference Sets

There are 10 different library reference sets available to engineer units. Names of sets, and components are as follows:

a. *Book Set, Celestial Navigation.*

(1) American Practical Navigator, NP9;
U.S. Navy Hydrographic Office

(2) Dutton's Navigation and Piloting; Hill, Utegaard, and Riordan

(3) Nautical Almanac; U.S. Naval Observatory

b. *Book Set, Topographic, General Purpose.*

(1) American Electricians Handbook; Craft
(2) Apparent Places of Fundamental Stars; International Astronomical Union

- (3) Tables of Squares, Cubes, Square Roots, Cube Roots and Reciprocals; Barlow
 - (4) Chemistry and Physics Handbook; Hodgman
 - (5) Computation of Traverse by Plane Coordinates, SP 624; CO-gs
 - (6) Definition of Terms Used in Geodetic and Other Surveys, SP 242; CO-gs
 - (7) Duttons Navigation and Piloting; Hill, Utegaard and Riordan
 - (8) Elements of Differential and Integral Calculus; Granville
 - (9) Elements of Map Projection, SP 68; CO-gs
 - (10) Formulas and Tables for the Computation of Geodetic Positions, SP 8; CO-gs
 - (11) General Theory of Polyconic Projections, SP 57; CO-gs
 - (12) Geodesy; Hosmer
 - (13) Horizontal Control Data, SP 227; CO-gs
 - (14) Instructions to Light Keepers on First Order Triangulations, SP 65; CO-gs
 - (15) Logarithmic Tables of Numbers and Trigonometric Functions; Von Vega
 - (16) Manual of Geodetic Astronomy; Determination of Longitude, Latitude, and Azimuth, SP 237; CO-gs
 - (17) Manual of Geodetic Leveling, SP 239; CO-gs
 - (18) Manual of Geodetic Triangulation, SP 247; CO-gs
 - (19) Manual of Leveling Computation and Adjustment, SP 240; CO-gs
 - (20) Manual of Natural Sine and Cosines to Eight Places, SP 231; CO-gs
 - (21) Manual of Photogrammetry; American Society of Photogrammetry
 - (22) Manual of Plane Coordinate Computation, SP 193; CO-gs
 - (23) Manual of Reconnaissance for Triangulation, SP 225; CO-gs
 - (24) Manual of Triangulation Computation and Adjustment, SP 138; CO-gs
 - (25) Mechanical Engineer's Handbook; Marks
 - (26) Natural Tables for the Computation of Geodetic Positions, Clark Spheroid of 1866, SP 241; CO-gs
 - (27) Natural Trigonometric Functions; Ives
 - (28) Numerical Mathematical Analysis; Scarborough
 - (29) Plane and Spherical Trigonometry; Kells, Kern and Bland
 - (30) Practical Astronomy; Nassau
 - (31) Signal Building, SP 234; CO-gs
 - (32) Star Azimuth Tables and Graphs for Latitudes 10 Degrees to 60 Degrees North, Publication G48; CO-gs
 - (33) State Coordinate Systems, SP 235; CO-gs
 - (34) Surveying Theory and Practice; Davis and Foote
 - (35) Tables for Polyconic Projection of Maps, SP 5; CO-gs
 - (36) Tide Tables, West Coast North and South America Including the Hawaiian Islands; CO-gs
 - (37) Isogonic Chart for 1955, United States; CO-gs
 - (38) Dictionary, Abridged
- c. Book Set, Topographic Battalion, Photomapping Company.*
- (1) American Electricians Handbook; Craft
 - (2) Elements of Map Projection, SP 68; CO-gs
 - (3) General Theory of Polyconic Projections, SP 57; CO-gs
 - (4) Logarithmic Tables of Numbers and Trigonometric Functions; Von Vega
 - (5) Manual of Photogrammetry; American Society of Photogrammetry
 - (6) Mechanical Engineer's Handbook; Marks
 - (7) Natural Trigonometric Functions; Ives
 - (8) Plane and Spherical Trigonometry; Kells, Kern and Bland
 - (9) Surveying Theory and Practice; Davis and Foote
 - (10) Tables for the Polyconic Projection of Maps, SP 5; CO-gs
- d. Book Set, Topographic Battalion, Reproduction Company.*
- (1) Chemistry of Lithography; Hartsuch
 - (2) Offset Plate Making, Surface, Book 502; Reed
 - (3) The Sensitivity Guide; Jorgensen and Bruno
 - (4) Dictionary, Abridged
- e. Book Set, Water Supply Company.*
- (1) Hydraulics Handbook; King, Wisler and Woodburn
 - (2) Laboratory Control of Water Purification; Cox
 - (3) Standard Methods for Examination of Water and Sewage; American Public Health Association

(4) Water Supply and Purification; Hard-
enburgh

(5) Water Supply Engineering; Babbitt
and Doland

f. Book Set, Forestry Operations.

(1) Civil Engineers Handbook; Trautwine

(2) Logging Principles and Methods of Har-
vesting Timber in the United States and Canada;
Brown

(3) Northeastern Loggers Handbook 6; De-
partment of Agriculture

(4) Surveying Theory and Practice; Davis
and Foote

*g. Book Set, Machinist, Welder and Electrical
Repair.*

(1) American Electricians Handbook; Craft

(2) Machine Tool Operations, Part I; Burg-
hardt

(3) Modern Refrigeration and Air Condi-
tioning; Althouse and Turnquist

(4) The New American Machinist Hand-
book; Calvin, Stanley and Legrand

(5) Welding Encyclopedia; McKenzie, Card
and Plumley

h. Book Set, Combat Group.

(1) American Electricians Handbook; Craft

(2) Asphalt Handbook, Construction Series
81; The Asphalt Institute

(3) Civil Engineering Handbook; Urquhart

(4) Construction Planning, Equipment, and
Methods; Peurifoy

(5) Data Book for Civil Engineers, Volume
I, Design; Seelye

(6) Handbook for Heavy Construction;
Stubbs

(7) Mechanical Engineer's Handbook;
Marks

(8) Modern Timber Engineering; Scofield
and O'Brien

(9) Simplified Engineering for Architects
and Builders; Parker

(10) Steel Construction; American Institute
of Steel Construction

i. Book Set, Construction Group.

(1) Architectural Graphic Standards; Ram-
sey and Sleeper

(2) Asphalt Handbook, Construction Series
81; The Asphalt Institute

(3) Asphalt Useful Tables, Construction
Series 78; The Asphalt Institute

(4) Concrete Inspection Manual; Kelly,
Bertin and Clair

(5) Construction Estimates and Costs; Pul-
ver

(6) Construction Specifications, Construc-
tion Series 80; The Asphalt Institute

(7) Data Book for Civil Engineers, Volume
II, Specifications and Costs; Seelye

(8) Electrical Engineer's Handbook, Elec-
trical Power; Pender and Delmar

(9) Handbook of Heavy Construction;
Stubbs

(10) Highway Engineering; Ritter and Pa-
quette

(11) Hydraulics Handbook; King, Wisler and
Woodburn

(12) Modern Refrigeration and Air Condi-
tioning; Althouse and Turnquist

(13) Railroad Curves and Earthwork; Allen

(14) Reinforced Concrete Design Handbook;
The American Concrete Institute

(15) Sewerage and Sewage Treatment; Bab-
bitt

(16) Soil Mechanics, Foundations and Earth
Structures; Tschebotarioff

(17) Specifications and Construction Meth-
ods for Hot Mix Asphalt Paving, SS-1; The
Asphalt Institute

(18) Structural Design in Metals; Williams
and Harris

(19) Surveying Theory and Practice; Davis
and Foote

j. Book Set, Field Army, Engineering Section.

(1) Construction Planning, Equipment and
Methods; Peurifoy

(2) CRSI Design Handbook; Concrete Re-
inforcing Steel Institute

(3) Design of Steel Structures; Bresler and
Lin

(4) Engineering Materials; The Committee
on Engineering Materials

(5) Mining Engineer's Handbook, Volume
I; Peele

(6) Mining Engineer's Handbook, Volume
II; Peele

(7) Pile Foundations; Chellis

Notes. 1. CO-gs is U.S. Coast and Geodetic Survey.

2. SP is Special Publication.

3. Texts referenced are latest year and edition.

B-17. Load Bearing Capacity of Ice

The strength of ice varies with the structure of the ice; the purity of the water from which it is formed; the cycle of formation (freezing, thawing, and refreezing); temperature; snow cover; and water currents. Table B-25 is based on the characteristics of good quality waterborne ice. It may be used as a guide until load tests are made to determine the actual load-bearing capacity of the ice.

Table B-25. Load Bearing Capacity of Ice

(1) Ice load-carrying capacity for personnel and equipment.

Load type	Gross weight (tons)	Minimum ice thickness (cm/in)	Minimum distance between loads (m/vd)
Soldier on skis or snowshoes	0.1	3/1.2	5/5.5
Soldier on foot	0.1	5/2	5/5.5
Infantry (column of 2)		7.6/3	7.3/8
Infantry (column of 4)		10/4	10/11
Wheeled vehicle loads up to	3.5	23/9	15/16.5
Wheeled vehicle loads up to	6.0	30/12	20/22
Wheeled vehicle loads up to	10.0	40/16	25.6/28
Wheeled vehicle loads up to	15.0	61/24	30/33
Tracked vehicle loads up to	3.5	20/8	15/16.5
Tracked vehicle loads up to	10.0	30/12	20/22
Tracked vehicle loads up to	12.5	40/16	25.6/28
Tracked vehicle loads up to	25.0	61/24	40/44
Tracked vehicle loads up to	45.0	71/28	50/55
Tracked vehicle loads up to	60.0	81/32	60/66

(2) Ice load-carrying capacity for sleds.

Ice thickness (cm/in)	Gross sled weight (tons)
15/6	1
17.5/7	2
23/9	5
33/13	10
40/16	15
46/18	20



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By Order of the Secretary of the Army:

Official:

VERNE L. BOWERS,
*Major General, United States Army,
The Adjutant General.*

W. C. WESTMORELAND,
*General, United States Army,
Chief of Staff.*

Distribution:

To be distributed in accordance with DA Form 12-11 requirements for Engineers Reference and Logistical Data.



Table 12-18. Tonedown Materials for Use On Concrete

Coating material	Container	Colors	Source	Durability	Preparation	Drying time (hr)	Climate limitations	Application	Coverage (sq ft per gal)	Thinners	Fire hazards during applications	Effects of jet exhaust at warmup points	Remarks
Cutback asphalt (coal, tar may be substituted).	55 gal drums	Brownish-black	*Commercial Fed-Spec. SS-A671.	Good	Ready mixed; quick-dry, medium-dry, slow-dry.	(med) 24	Requires dry surface and conditions. May be used at sub-freezing temperatures.	Brushing, Spraying, Distributor.	80 to 100	Quick-gasoline Medium-kerosene Slow-diesel fuel	High. If coating is heavy will support combustion if fired by jet exhaust or other means.	Melting increases shininess and slipperiness. Possible fire.	Not recommended for surface exposed to jet exhaust.
Coating compound, bituminous emulsion.	55 gal drums	Brownish-black	*Commercial MIL-P-3840	Good	Ready mixed	48	Can be applied to damp surface. Temperature must be above 45° F. Not good in tropics.	Brushing, Spraying, Distributor.	Approx 50	None	Low	Will remove Better than cutback asphalt but has similar drawbacks.	Surface coated cannot later be painted with last- ing success with any other type paint.
Paint, water paste	5 gal can	All camouflage colors except desert sand & light green.	*Commercial MIL-P-13340.	Fair	Must be thinned w/ gasoline or water, 1 to 1 by volume. Use gas or naphtha below freezing.	6	Can be applied to damp surface. Good between -40° and +160° F.	Brushing, Spraying	400 to 500	Water, gasoline, and naphtha.	High when gasoline & naphtha are used. Low with water.	Will remove but will not support its own combustion.	None.
Pigmented sodium silicate.	Varies	All camouflage colors.	*Commercial	Good on rough surface, poor on smooth.	Concentrate thinned w/water is sprayed on surface followed by spraying with calcium chloride to set or fix.	N/A	Can be applied to damp surface.	Spraying, Distributor.	Not available	Water	None	Not available	Good for limited types of surface. Traffic on smooth surface pulverizes brittle coating which then blows away or washes off.
Xylene and tar (Rt. 2). Kerosene & asphalt (similar to British pitch and creosote mix).	Varies	Brownish-black	*Commercial	Fair	Mix 80 tar to .20 xylene. Mix 25 asphalt to 75 kerosene by volume.	Rapid	Dry, clean surface required.	Spraying Distributor.	Approx 200	Xylene kerosene	High	Will remove. No fire hazard with thin film, may be with thick film.	Primarily a cheap stain. Has application and fire drawbacks.

*Material has no specification, is made up in camouflage colors commercially.

Table 12-11. Coating and Staining Materials

Material	Unit 4	Gravity				Bulkhead				Earth revetment	Free standing wall		Standoff				
		Logs	Dimensioned timber	Landing mat	Steel sheet pile	Logs	Dimensioned timber		Landing mat		Steel sheet pile	Reinforced concrete	Soil cement	Logs	Dimensioned timber	Expanded metal lath	Steel sheet pile
							Field erect	Prefab									
Filler (earth) -----	cu yd -----	$0.4 \left(TH + \frac{H^2}{2} \right)$	$0.4 \left(TH + \frac{H^2}{2} \right)$	$0.4 \left(TH + \frac{H^2}{2} \right)$	$0.4 \left(TH + \frac{H^2}{2} \right)$	0.4TH	0.4TH	0.4TH	0.4TH	0.4TH	0.4(TH+H ²)	NA	NA	NA	NA	NA	NA
Sheathing ² -----	sq ft -----	10(H+1)	10H	10H ²	10(H+2)	20H	20H	2H(T+10)	20H ²	20(H+2)	NA	NA	NA	10(H+2)	10H	10H	10(H+2)
Waterproofing material -----	sq yd -----	NA	1.1H	NA	NA	NA	2.2H	2.2H(T+10)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cover material -----	sq yd -----	1.1T+1.7H	1.1T+1.7H	1.1T+1.7H	1.1T+1.7H	1.1(T+2)	1.1(T+2)	1.1(T+2)	1.1(T+2)	1.1(T+2)	NA	NA	NA	NA	NA	NA	NA
Scabbing ³ -----	lin ft -----	100	100	100	100	150	2TH+100	NA	100	100	NA	NA	NA	100	100	50	50
Wire rope cable ⁴ -----	lin ft -----	6H+9T+27	12H+18T+54	6H+9T+18	8H+12T+24	24T+96	18T+72	NA	18T+72	15T+60	NA	NA	NA	9H+12	NA	NA	9H+12
Cable clamps -----	ea -----	60	110	60	75	150	110	NA	110	80	NA	NA	NA	18	NA	NA	18
Nails and spikes -----	lb -----	100	100	20	20	150	150	150	20	20	NA	NA	NA	100	100	20	20
Vertical supports -----	lin ft -----	11(H+3) (2 sizes)	11(H+2)	6(H+2)	NA	12(H+2)	22(H+2)	4H	22(H+2)	NA	NA	NA	NA	NA	3H+6	2H	NA
Wales -----	lin ft -----	NA	NA	NA	3.3H	NA	NA	H(T+10)	NA	3.3H	NA	NA	NA	40	3H	NA	NA
Braces -----	lin ft -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.2H	NA	NA
Soil retainer -----	sq yd -----	1.1(H+1)	NA	1.1(H+1)	NA	2.2(H+1)	NA	NA	2.2(H+1)	NA	NA	NA	NA	NA	NA	NA	NA
Concrete -----	cu yd -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4T(H+2)+0.4H (24 in. footer).	NA	NA	NA	1	NA
Cement -----	cu ft (sack) -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	TH+0.1H ²	NA	NA	NA	NA
Reinforcing bars -----	lin ft -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11T+27H+11	NA	NA	NA	NA	NA
Soil ⁵ -----	cu yd -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.36(TH+.1H ²)	NA	NA	NA	NA

¹ Material waste factors are not included in estimates. Add 20 percent waste factor for sheathing and 10 percent waste factor for all other materials. Ends (corners) not included; they should be considered in addition to the normal waste factor. All dimensions are in feet.

² For one layer only. Multiply by number of layers if laminated.

³ Scabbing is reusable.

⁴ Key to symbols: H—height in feet
T—thickness in feet

⁵ Increase H to next higher multiple of mat width.

⁶ For soil cement only.

⁷ Estimate based on group of three anchor cables on 10-foot vertical support at intervals specified in drawing.

Table 12-12. Coverage Data

Coating material	Surfaces																																													
	Asphalt, macadam, bituminous surfaces, tar-coated roofing paper					Concrete, stucco, brick, building etone, slate					Glass		Coated or primed metal				Galvanized metal				Mineral coated roofing				Rubber				Wood				Grass			Earth, sand & stabilized soil			Glass fiber & steel wool		Feather gar- nished & mineral fiber-garnished netting		Wood chips & other texturing materials			
	Brushing		Spraying			Brushing		Spraying			Brushing		Spraying		Brushing		Spraying		Brushing		Spraying		Brushing		Spraying		Brushing		Spraying		Spraying			Spraying			Spraying		Spraying							
Sq ft per gal	Man hrs per 100 sq ft	Sq ft per gal	Sprayer sq ft per hr	Pressure distributor sq ft per min	Sq ft per gal	Man hrs per 100 sq ft	Sq ft per gal	Sprayer sq ft per hr	Pressure distributor sq ft per min	Sq ft per gal	Man hrs per 100 sq ft	Sq ft per gal	Sq ft per hr	Sq ft per gal	Man hrs per 100 sq ft	Sq ft per gal	Sq ft per hr	Sq ft per gal	Man hrs per 100 sq ft	Sq ft per gal	Sq ft per hr	Sq ft per gal	Man hrs per 100 sq ft	Sq ft per gal	Sq ft per hr	Sq ft per gal	Man hrs per 100 sq ft	Sq ft per gal	Sq ft per hr	Sq ft per gal	Sprayer sq ft per hr	Pressure distributor sq ft per min	Sq ft per gal	Sprayer sq ft per hr	Pressure distributor sq ft per min	Sq ft per gal	Sprayer sq ft per hr	Sq ft per gal	Sprayer sq ft per hr	Sq ft per gal	Sprayer sq ft per hr					
Paint, Water, Paste, MIL-P-13840	450	1	600	3000	N/A	400	1	500	3000	N/A	600	1	750	3000	600	1	750	3000	600	1	750	3000	450	1	600	3000	450	1	600	3000							600	3000	600	6000	300	3000				
Xylene & Tar (R-2); Kerosene & Asphalt.						200	1	200	2040	6000																																				
Paint, Temporary, Paste, MIL-P-13983.											500	1	600	3000	500	1	600	3000																												
Cutback Asphalt Types I, II, III Fed SSA-671.	30	1.66	30	900	2400	100*	1*	100*	2000*	8000*	30	1.66	30	900	30	1.66	30	900	30	1.66	30	900	30	1.66	30	900					30	1.66	30	900	100	2000	8000	100	2000	8000						
						30**	.15**	30**	900**	2400**																																				
Used Crankcase Oil						50	1	50	1500	4000																																				
Stains																													200	1	200	3000												200	3000	
Coating Compound, Bituminous Emul-sion, MIL-P-3840.	45	1.1	45	1350	3600	45	1.1	45	1350	3600	45	1.1	45	1350	45	1.1	45	900	45	1.1	45	1350	45	1.1	45	1350			45	1.1	45	1350	100	2000	8000	100	2000	8000								
Asphalt Cement	50	.2	50	N/A	4000	50	.2	50	N/A	4000																																				

*Outback Asphalt Types II and III only.
**Outback Asphalt Type I only.

Table 12-10. Adhesive Table

Adhesives	Source	Durability	Preparation	Climate limitations	Application	Coverage (Sq ft per gal)	Recommended surface	Suggested texturing materials	Remarks Coating material
Cutback asphalt	Commercial Fed Spec SS-A671.	Good	Ready Mixed	Requires dry surface. May be used in sub-freezing temperatures.	Brushing, spraying, distributor.	30-100	Concrete	Rock chips, gravel aggregate (the heavier texturing materials).	Not recommended for surface exposed to jet exhaust. Texturing materials applied after adhesive becomes tacky (10-15 minutes).
Coating Compound Bituminous Emulsion.	Commercial MIL-P-3840 ...	Good	Ready Mixed	Can be applied to damp surface. Temperature must be above 45° F. Not good in the tropics.	Brushing, spraying, distributor.	Approximately 50	Concrete	Asphalt chips, rubber chips, wood chips, other small granules.	Texturing materials applied after adhesive becomes tacky (10-15 minutes).
Green Vegetation (Field Expedient).	Practically all green vegetation.	Good binding strength	Pack fresh cut vegetation (remove woody sections) in metal buckets 2/3 full. Cover w/water; Boil 1/2 hour, pour off & discard vegetation. Reboil liquid to desired consistency. (12-15 buckets of veg.-1 gal. adhesive.)	Heat and cold have no effect. Prolonged exposure to rain and high humidity will affect it.	Brushing	1,000 on smooth nonporous surface 400-500 on rough surface.	Vehicle metal, glass, wood, fabrics.	Sand, soil, ashes, wood litter, leaves, grasses, bark, twigs.	Apply adhesive in small patches, adding texturing material to each before starting new area.
Starch (Field Expedient)	Flour, ground grains, potatoes, non-fibrous vegetables, whole grain, any other food containing starch.	Excellent on rough surface, good on smooth surface.	Boil with water; stir smooth thin to correct consistency. Strain out extraneous materials.	Heat and cold have no effect. Prolonged exposure to dry heat results in some peeling from smooth surfaces.	Brushing rags by hand ...	160-250 on smooth surface 80-105 rough surface.	Wood, metal, fabric	Sand, light soils, other light weight granules.	When a heavier coating is needed mix sand and adhesive to make a thick paste and spread by hand or paddle. Then dust with dry sand while surface is still moist.
Raw Molasses (Field Expedient) ..	Commercial, sugar refineries.	Unstable	Ready Mixed	Not waterproof	Distributor, spraying brushing.	Depending on thickness 5-20.	Earth, wood fabrics	Very light weight materials.	Recommended in extreme emergency only. Never dries, and is always sticky.

Table 11-3. Characteristics of Crew Served Infantry and Artillery Weapons Emplacements

	1	2	8	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Type of emplacement or shelter	Protection afforded ¹						Total construction time in man-hours for construction with D-handle shovels and ordinary carpentry tools ⁴					Weight and volume of materials								
		Nuclear weapons effects ²				Conventional weapons effects ³							Revetment materials for cover support only				Complete revetment				
		Nuclear radiation transmission factors			Fortification protection factor	Thermal effects	Tracked vehicles	Artillery fragments	Revetment materials for cover support only		Complete revetment		No revetment materials used	Corrugated metal construction ⁶		Sized lumber construction		Corrugated metal construction ⁶		Sized lumber construction	
		Initial gamma	Initial neutron	Residual gamma ⁵					Corrugated metal const	Sized lumber const	Corrugated metal const	Sized lumber const		Weight (lb)	Volume (cu ft)	Weight (lb)	Volume (cu ft)	Weight (lb)	Volume (cu ft)	Weight (lb)	Volume (cu ft)

CHARACTERISTICS of CREW SERVED WEAPONS EMPLACEMENTS

2	Open automatic rifle emplacement	0.1	0.3	0.1	65	Very good	Good	Fair	NA	NA	7.0	8.0	4.0	4.0	NA	NA	NA	170	3.0	200	6.0
3	Automatic rifle emplacement with 18" of cover.	0.07	0.2	0.02	55	Very good	Virtually none	Good	4.0	5.0	6.0	7.0	NA	45	0.5	70	2.0	220	4.0	270	10.0
4	Open horseshoe-type machinegun emplacement.	0.15	0.4	0.1	70	Good	Fair	Fair to good	NA	NA	5.0	7.0	2.0	NA	NA	NA	NA	280	5.0	450	14.0
5	Open two 1-man foxhole-type light machinegun emplacements.	0.1	0.3	0.1	65	Very good	Good	Good	NA	NA	6.0	7.0	4.0	NA	NA	NA	NA	530	10.0	640	20.0
6	Horseshoe-type light machinegun emplacement with full cover.	0.06	0.2	0.003	55	Very good	Fair	Very good	9.0	11.0	11.0	14.0	NA	190	4.0	250	7.0	720	13.0	890	27.0
7	Two 1-man foxhole-type light machinegun-type emplacement with ½ cover and adjoining shelter.	0.015	0.03	0.0005	30	Excellent	Good	Excellent	15.0	22.0	19.0	28.0	NA	250	2.5	630	20.0	520	7.5	850	30.0
8	Circular-type .50 cal machinegun emplacement.	0.3	0.5	0.15	80	Fair	Fair	Fair	NA	NA	14.5	16.5	10.0	NA	NA	NA	NA	300	5.0	420	13.0
9	Pit-type emplacement for 3.5-inch rocket launcher.	0.3	0.5	0.15	80	Fair	Fair	Fair	NA	NA	5.0	6.0	3.0	NA	NA	NA	NA	110	1.0	160	5.0
10	81-mm mortar emplacement	0.4	0.7	0.3	85	Good	Virtually none	Fair	NA	NA	12.0	NA	NA	NA	NA	NA	NA	210	3.0	NA	NA
11	4.2-inch mortar emplacement	0.4	0.7	0.3	85	Good	Virtually none	Fair	NA	NA	29.0	NA	NA	NA	NA	NA	NA	370	6.0	NA	NA
12	Recoilless rifle position (mounted)	0.4	0.6	0.2	80	Fair	Virtually none	Fair	NA	NA	NA	NA	30.0	NA	NA	NA	NA	NA	NA	NA	NA
13	Recoilless rifle position (dis-mounted).	0.5	0.7	0.2	85	Fair	Virtually none	Fair	NA	NA	NA	NA	17.0	NA	NA	NA	NA	NA	NA	NA	NA

CHARACTERISTICS of ARTILLERY WEAPONS EMPLACEMENTS

14	105-mm howitzer emplacement	0.6	0.8	0.6	90	Good	Virtually none	Fair	NA	NA	NA	NA	100.0	NA	NA	NA	NA	NA	NA	NA	NA
15	155-mm howitzer emplacement	0.6	0.8	0.6	90	Good	Virtually none	Fair	NA	NA	NA	NA	170.0	NA	NA	NA	NA	NA	NA	NA	NA

¹ Protection afforded assumes the occupants of fortifications are in the most protected position of their fortifications. For most fortifications, protection decreases as the angle of sight from the position to the center of the weapon burst increases.

² For blast effects, see FM 5-15, paragraph 1-8c.

³ For direct fire weapons effects, see FM 5-15, paragraph 1-6.

⁴ Assume normal digging capability in daylight with trained troops.

⁵ Assumes fallout is kept out of hole at surface level by some sort of cover.

⁶ May include wooden framing and braces.

Note. Classification of Fortification by Attenuating of Residual Radiation.

a. Fortifications may be generally classified according to their attenuation of residual radiation. Such classification is shown below:

Fallout Attenuation Classifications

Transmission factors	Classification	General guidance in high-level radiation field
Less than 0.001	Excellent	Remain in place.
0.001 to 0.005	Good	Probably remain in place.
0.005 to 0.01	Fair	Probably leave position at optimum time.
More than 0.01	Poor	Leave position at optimum time.

b. A general idea of the dose to be expected with the classification shown above is tabulated below, using a fallout arrival time of H + 1 and a stay time of 96 hours. Under these conditions, the total incident dose in rad is exactly three times the dose rate of H + 1. Assuming an H + 1 dose of 5,000 rad/hour:

Interior Dose for Various Fallout Classification

Classification	Total dose
Excellent	Less than 15 rad
Good	15 to 75 rad
Fair	75 to 150 rad
Poor	More than 150 rad

Table 11-2. Characteristics of Personnel and Individual Weapons Emplacements

1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Type of emplacement or shelter	Protection afforded ¹							Total construction time in man-hours for construction with D-handle shovels and ordinary carpentry tools ²					Weight and volume of materials							
		Nuclear weapons effects ³				Conventional weapons effects ³								Revetment materials for cover support only				Complete revetment			
		Nuclear radiation transmission factors			Fortification protection factor	Thermal effects	Tracked vehicles	Tritillary fragments	Revetment materials for cover support only		Complete revetment		No revetment materials used	Corrugated metal construction ⁴		Sized lumber construction		Corrugated metal construction ⁵		Sized lumber construction	
		Initial gamma	Initial neutron	Residual gamma ⁵					Corrugated metal const	Sized lumber const	Corrugated metal const	Sized lumber const		Weight (lb)	Volume (cu ft)	Weight (lb)	Volume (cu ft)	Weight (lb)	Volume (cu ft)	Weight (lb)	Volume (cu ft)
2	Improved crater -----	0.6	0.8	0.3	90	Fair	Virtually none	Better than in open	NA	NA	NA	NA	0.5	NA	NA	NA	NA	NA	NA	NA	NA
3	Skirmishers trench -----	0.8	0.9	0.5	95	Fair	Virtually none	Better than in open	NA	NA	NA	NA	0.5	NA	NA	NA	NA	NA	NA	NA	NA
4	Prone emplacement -----	0.4	0.7	0.2	85	Good	Virtually none	Fair	NA	NA	NA	NA	1.5	NA	NA	NA	NA	NA	NA	NA	NA
5	Open one-man foxhole -----	0.09	0.3	0.1	65	Very good	Good	Good	NA	NA	3.5	4.5	2.0	NA	NA	NA	NA	190	3.5	240	8
6	Open one-man foxhole with offset	0.004	0.008	0.00001	20	Excellent	Very good	Excellent	9.0	14.0	10.0	16.0	NA	50	0.6	180	5.5	240	4.0	420	13.0
7	One-man foxhole with half cover	0.08	0.2	0.04	55	Very good	Fair (—)	Very good	2.5	3.0	4.5	5.5	NA	10	0.1	20	0.6	200	3.5	260	8.0
8	One-man foxhole with half cover and offset.	0.003	0.008	0.00001	20	Excellent	Very good	Excellent	10.0	14.0	12.0	18.0	NA	60	0.7	200	6.0	250	4.0	440	14.0
9	Open two-man fox-hole -----	0.1	0.3	0.1	65	Good	Good	Good	NA	NA	6.0	8.0	3.0	NA	NA	NA	NA	280	5.0	320	10.0
10	Deepened two-man foxhole -----	0.07	0.15	0.1	55	Very good	Good	Very good	NA	NA	8.0	10.0	5.0	NA	NA	NA	NA	300	5.5	375	12.0
11	Two-man foxhole with half cover -----	0.09	0.2	0.04	60	Very good	Fair to good	Very good	4.0	4.0	8.0	10.0	NA	15	0.2	32	1.0	280	5.0	350	11.0
12	Two-man foxhole with half cover and two offsets.	0.002	0.003	0.00001	15	Excellent	Very good	Excellent	20.0	30.0	22.0	35.0	NA	120	1.5	400	12.0	380	6.0	700	22.0
13	Two-man foxhole with half cover and adjoining shelter.	0.01	0.02	0.0005	30	Excellent	Good	Excellent	11.0	17.0	13.0	22.0	NA	100	1.2	560	18.0	460	7.0	880	28.0
14	Open fighting trench (25' length)*	0.4	0.7	0.3	85	Good	Fair	Fair	NA	NA	28.0	32.0	21.0	NA	NA	NA	NA	490	8.0	710	22.0
15	Fighting trench with full cover (25' length).	0.15	0.4	0.03	70	Excellent	Fair	Very good	27.0	29.0	35.0	40.0	NA	240	4.0	360	11.0	730	12.0	1,060	33.0

¹ Protection afforded assumes the occupants of fortifications are in the most protected position of their fortifications. For most fortifications, protection decreases as the angle of sight from the position to the center of the weapon burst increases.

² For blast effects, see FM 5-15, paragraph 1-8a.

³ For direct fire weapons effects, see FM 5-15, paragraph 1-6.

⁴ Assume normal digging capability in daylight with trained troops.

⁵ Assumes fallout is kept out of hole at surface level by some sort of cover.

⁶ May include wooden framing and braces.

Note. Classification of Fortification by Attenuating of Residual Radiation.

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More than 0.01	Poor	Leave position at optimum time.
b. A general idea of the dose to be expected with the classification shown above is tabulated below, using a fallout arrival time of H + 1 and a stay time of 96 hours. Under these conditions, the total incident dose in rad is exactly three times the dose rate of H + 1. Assuming an H + 1 dose of 5,000 rad/hour:		
Interior Dose for Various Fallout Classification		
Classification	Total dose	
Excellent	Less than 15 rad	
Good	15 to 75 rad	
Fair	75 to 150 rad	
Poor	More than 150 rad	

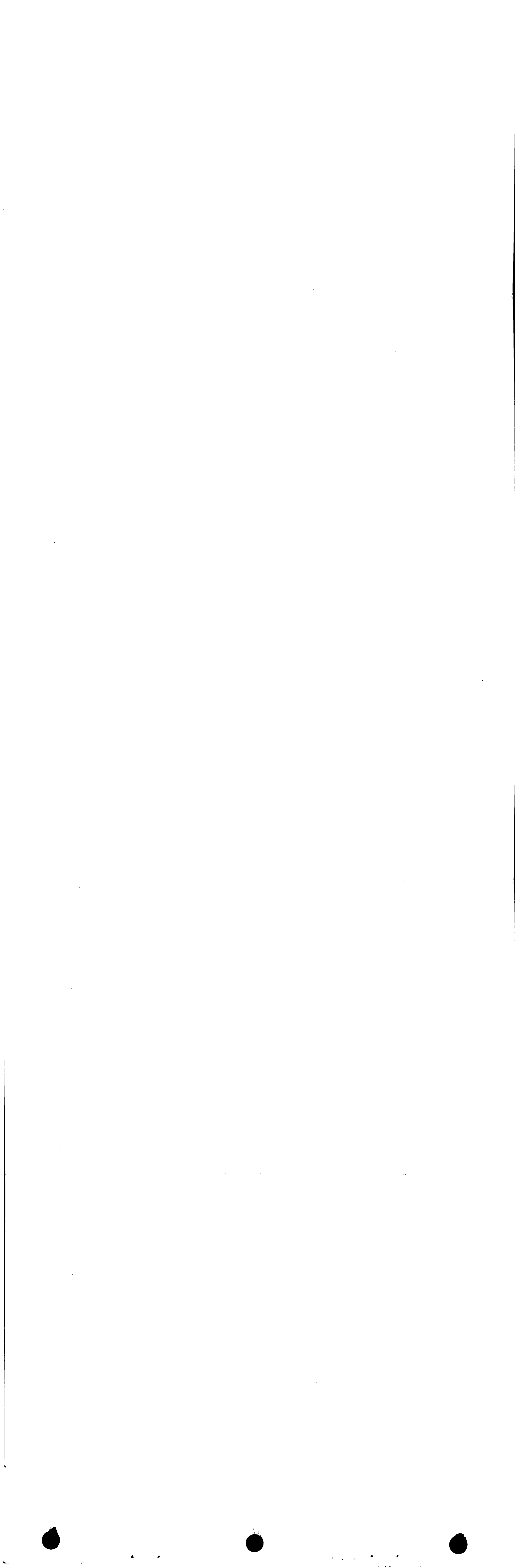


Table 10-8. Minefield Data Summary Sheet

Type of field	Required authority	Tactical employment	Type of mines	Marking required	Removal required	Reports required	Records required	Recommended minimum density	Patterns	Remarks
Protective 1. Hasty 2. Deliberate	* 1. Hasty - Battalion or higher may delegate authority down to commander of company size units. On specific occasions to a platoon leader for an operational mission 2. Battalion or higher, not delegated lower than commanders of company size units.	1. Temporary position protection. a. Forward and rear areas or in isolated locations. b. Examples: outpost, working parties, roadblocks defense parties. 2. Static installation protection. Part of perimeter security of depots, airfields, static missile sites and other installations.	Metallic, antitank, antipersonnel, directional antipersonnel mines (e.g., M18 type), flares, flame mines of detectable type. Mines difficult to detect (e.g., non-metallic) and chemical mines are not employed. Antihandling devices are not used.	Marked and/or guards posted to protect friendly troops.	Yes, removal required by laying unit unless relieving unit commander specifically requests them to be left in place. Report of transfer sent to lowest commander having command over both units involved.	1. a. Intention to lay. b. Initiation of laying. c. Completion of laying. d. Report of change if any. e. Report of transfer. Forward reports to parent unit commander. 2. Same as for Hasty Protective Reports forwarded to division HQ or equivalent HQ.	1. Hasty Protective Minefield Record forms. Forward to parent unit commander. 2. Standard form with at least minimum information. Forward to division.	Vary with the primary threat, and type of mines used.	None specified.	1. Locate within small arms range but beyond hand grenade range of the defender's position. 2. Normally laid on short notice with mine basic loads and local stocks.
Defensive	* Division and higher commanders. May not be delegated lower than brigade and comparable commanders.	Prevent or limit penetration into or between positions of company, battalion, or brigade defense areas and to strengthen the defense in accordance with a tactical plan employed to delay and disorganize enemy attacks; to disrupt, canalize and assist in the destruction of enemy mobility and to strengthen manned weapons and obstacle systems.	All types of mines, antihandling devices and flares. Chemical mines may be used when authorized by appropriate authority. Approximately 5% of antitank mines fitted with antihandling devices; flares, noisemakers, and smoke streamers should be laid to warn of enemy breaching attempts.	As required to protect friendly troops and civilians. Normally the standard marking fence with the markers is used.	No, if responsibility is transferred, report will be completed as protective minefield.	1. Intention to lay. 2. Initiation of laying. 3. Completion of laying. 4. Progress (optional). 5. Report of change. 6. Report of transfer. Forward completion report to Army headquarters or comparable headquarters level.	Standard form with at least minimum information. A record of change is required if field is altered. Forward to Army headquarters.	1. Antitank minefield - One antitank, and two antipersonnel mines per meter of minefield trace. 2. Antipersonnel minefield - one fragmentation, and two blast antipersonnel per meter of trace.	Normally the standard pattern will be used.	1. Minimum depth: Antitank Minefield - 100 meters. Antipersonnel Minefield-50 meters. 2. Location coordinated with division plans. 3. Cover by artillery, automatic, and antitank fire.
Barrier	* Corps and higher commanders. May not be delegated lower than division or comparable commanders.	Employed to block enemy attack formation in selected areas, including flank and rear areas and to canalize his approach into selected battle areas. Usually preplanned and integrated into field army, corps, and division barrier plans. Employed to canalize, disrupt and delay enemy attack. To provide time for defender to concentrate fire and reserves. Also used to direct the enemy attack which enables the defender to attack with blocking or counterattacking forces.	All types of mines, antihandling devices, and flares may be used. Extensive use of complex fusing. Chemical mines may be used if authorized. Approximately 20% of antitank mines equipped with antihandling devices.	As required to protect friendly troops. Normally the standard marking fence with markers is used.	No	1. Intention to lay. 2. Initiation of laying. 3. Progress of laying (as required). 4. Completion of laying. 5. Change of field. 6. Report of transfer. Completion report to Army headquarters.	Standard form with at least minimum information. Forward to Army headquarters. Record of change is required.	Antiminefield - Three antitank, six blast antipersonnel mines per meter minefield trace. Antiminefield - Two fragmentation, four blast mines per meter of trace.	Standard, nonstandard pattern and scattered mining is authorized.	1. Minimum depth: Anti Minefield - 300 meters. Antipersonnel Minefield-120 meters. 2. Cover by observation with prepared artillery and air support plans.
Nuisance	* Army commander or higher. May be delegated to division or comparable commanders.	To delay, disorganize and lower morale of advancing enemy; to hinder his use of an area or route. Particularly effective in retrograde movement, denial operations, and during evacuation.	All types of antitank and antipersonnel mines, bobytraps and dirty trick devices. If time permits all antitank mines should be equipped with antihandling devices.	None unless initially to protect friendly troops.	No	1. Intention to lay. 2. Initiation of laying. 3. Progress optional. 4. Completion of laying. 5. Change of field. 6. Report of transfer. Completion report to Army headquarters	Standard form forwarded to Army headquarters.	None specified.	None specified.	1. May or may not be covered by fire. 2. A boobytrapped area is considered a nuisance minefield.
Phony	* The commander who has the authority to employ the type field simulated.	Used when lack of time, personnel, or material prevents laying a live minefield. Used to deceive the enemy into thinking area is mined. Used to extend or supplement live fields. (Camouflage gaps in live fields).	Phony mines only, ground disturbed to simulate live mines. Metal (cans, scrap, etc) used to give false signals on detector sets.			Same as for the type field simulated				1. Planning and coordination for laying and fire coverage must be done with same care as type field being simulated.

*All abandoned minefields become enemy minefields.

Table 8-6. Basic Airfield Expedient Surfacing Requirements

Airfield type	Typical sector	Anticipated service life	Possible using aircraft US type	Runway, taxiway, and apron surfacing requirements for airfield index of						Overrun area and shoulder surfacing requirements for airfield index of					
				5-6	6-8	8-10	10-12	12-15	15 or greater	5-6	6-8	8-10	10-12	12-15	15 or greater
Battle area:															
Light lift	Brigade base	3-days	C-7A ^a	U	U	U	U	U	U	U	U	U	U	U	U
Medium lift	Brigade base	↓	C-130 ^a C-123	(4d) (4d)	U	U	U	U	U	(2d) (4d)	U	U	U	U	U
Forward area:		2 weeks													
Liaison	Division or brigade base	↓	O-1 ^a	U	U	U	U	U	U	U	U	U	U	U	U
Surveillance	Division base	↓	OV-1 ^a	(3d) LM	LM	U	U	U	U	(2d) (4d)	U	U	U	U	U
Light lift	Division base	↓	C-7A ^a	(3d) (5d)	U	U	U	U	U	(4d) (3d)	U	U	U	U	U
Medium lift	Division base	↓	C-130 ^a C-7A	(5d) (5d)	LM	LM	U	U	U	(4d) (4d)	U	U	U	U	U
Support area:		1-2 mo													
Liaison	Corps area	↓	O-1 ^a	U	U	U	U	U	U	(2d) (5d)	U	U	U	U	U
Surveillance	Corps area	↓	OV-1 ^a	(3d) LM	LM	U	U	U	U	(5d) (3d)	U	U	U	U	U
Light lift	Corps area or FASCOM ^b	↓	C-7A ^a	(5d) (4d)	U	U	U	U	U	(3d) (3d)	U	U	U	U	U
Medium lift	Corps area or FASCOM	↓	C-130 ^a C-7A	(4d) (4d)	MM	MM	LM	U	U	(3d) (3d)	LM	U	U	U	U
Heavy lift	Corps area or FASCOM	↓	C-124 ^a C-141 ^a	I	MM	MM	LM	LM	U	(3d) (3d)	LM	LM	LM	U	U
Tactical	Corps area or FASCOM	↓	F-4C ^a	MM	MM	MM	LM	LM	LM		LM	LM	LM	LM	U
Rear area:		6-12 mo													
Army	COMMZ ^c	↓	OV-1 ^a C-7A O-1	LM (5d)	LM	LM	U	U	U	(5d) (4d)	U	U	U	U	U
Medium lift	COMMZ	↓	C-130 ^a	I	MM	MM	LM	LM	U	(6d) (4d)	LM	LM	U	U	U
Heavy lift	COMMZ	↓	C-141 ^a C-135 ^a C-133	I	I	MM	MM	LM	LM	(8d) (3d)	MM	LM	LM	LM	U
Tactical	COMMZ	↓	F-4C ^a F-105 ^a F-100 F-101 F-104	I	MM	MM	MM	LM	LM	(7d) (4d)	LM	LM	LM	LM	U

NOTE: U = unsurfaced soil with or without membrane, MM = medium duty mat, LM = light duty mat, and I = subgrade airfield index must be increased to that required for medium duty mat.

^a = Particular aircraft that is critical in load and/or ground run, from which area requirements, geometrics, and expedient surfacing requirements were developed.

^b = Field Army Support Command.

^c = Communication zone.

^d = Minimum airfield index.



Table 8-5. Characteristics of Soils Pertinent to Battle, Forward, Support, and Rear Area Airfields

Major Divisions (1) (2)		Symbol			Name (6)	Value as a Subgrade Beneath Landing Mat or as an Unsurfaced Area		Freedom of Dry Surfaces from Dust		Drainage Characteristics (11)	Compaction Equipment (12)	Unit Dry Weight lb per cu ft (13)	Airfield Index (14)
		Letter (3)	Hatching (4)	Color (5)		Dry (7)	Wet (8)	Firm Surface (9)	Loose Surface (10)				
COARSE- GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Excellent	Excellent to good	Excellent to good	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller, vibratory compactors.	125-140	NA
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Very good	Excellent	Excellent to good	Excellent to good	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller, vibratory compactors.	110-140	NA
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Excellent	Very good	Good	Good to fair	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	125-145	NA
						Excellent	Good	Good	Good to fair	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	115-135	NA
		GC		Clayey gravels, gravel-sand-clay mixtures	Excellent	Good	Good	Good to fair	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	130-145	NA	
	SAND AND SANDY SOILS	SW		Red	Well-graded sands or gravelly sands, little or no fines	Very good	Very good	Good	Good to fair	Excellent	Crawler-type tractor, rubber-tired roller, vibratory compactors.	110-130	NA
		SP			Poorly graded sands or gravelly sands, little or no fines	Good	Very good	Good	Fair	Excellent	Crawler-type tractor, rubber-tired roller, vibratory compactors.	105-135	10-15
		SM		Yellow	Silty sands, sand-silt mixtures	Very good	Good	Fair	Fair to poor	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	120-135	13-15
						Very good	Fair	Fair	Fair to poor	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-130	10-15
		SC		Clayey sands, sand-clay mixtures	Very good	Fair	Fair	Fair to poor	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-135	7-15	
FINE- GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Good	Very poor	Fair to poor	Poor	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	90-130	13 or less
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Good	Poor	Fair to poor	Poor	Practically impervious	Rubber-tired roller, sheepsfoot roller	90-130	13 or less
		OL			Organic silts and organic silt-clays of low plasticity	Good	Very poor	Fair to poor	Poor	Poor	Rubber-tired roller, sheepsfoot roller	90-105	7 or less
	SILTS AND CLAYS LL IS GREATER THAN 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Good	Very poor	Good to fair	Poor	Fair to poor	Sheepsfoot roller, rubber-tired roller	80-105	10 or less
		CH			Inorganic clays of high plasticity, fat clays	Good	Poor	Good to fair	Poor	Practically impervious	Sheepsfoot roller, rubber-tired roller	90-115	13 or less
		OH			Organic clays of medium to high plasticity, organic silts	Good	Very poor	Good to fair	Poor	Practically impervious	Sheepsfoot roller, rubber-tired roller	80-110	7 or less
		Pt			Orange	Peat and other highly organic soils	Very poor	Extremely poor	Good	Poor	Fair to poor	Compaction not practical	--

Note:

- Column 3, division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is on basis of Atterberg limits; suffix d (e.g., GMd) will be used when the liquid limit is 25 or less and the plasticity index is 5 or less; the suffix u will be used otherwise.
- In the first 7 items of columns 7 and 8, where gravel, gravelly soils, sands, or sandy soils are used in an unsurfaced area, they should be stabilized to prevent aircraft damage from loose particles. Landing mat will not usually be required on these soils. Where landing mat is used which does not have a flat bottom surface, a cushion layer of fine sand or some other similar fine-grained material will be required for seating of the mat.
- In column 12, the equipment listed will usually produce the required densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled. In some instances, several types of equipment are listed because variable soil characteristics within a given soil group may require different equipment. In some instances, a combination of two types may be necessary.
 - Unsurfaced areas. Steel-wheeled and rubber-tired rollers are recommended for hard, angular materials with limited fines or screenings. Rubber-tired equipment is recommended for softer materials.
 - Areas to be surfaced with landing mat. Rubber-tired equipment is recommended for rolling during final shaping operations for most soils and processed materials.
 - Equipment size. The following sizes of equipment are necessary to assure the high densities required for airfield construction:
 - Crawler-type tractor -- total weight in excess of 30,000 lb.
 - Rubber-tired tractor -- wheel load in excess of 15,000 lb.
 - Sheepsfoot roller -- wheel loads as high as 40,000 lb may be necessary to obtain the required densities for some materials (based on contact pressure of approximately 65 to 150 psi).
 - be at least 5 percent of the total peripheral area of the drum, using the diameter measured to the faces of the feet.
- Column 13, unit dry weights are for compacted soil at optimum moisture content for CE 55 (modified AASHTO) compaction effort.
- Column 14, NA indicates that the airfield index is greater than 15. This is the maximum value which can be measured by the airfield cone penetrometer.
- Columns 9 and 10, wet or damp soils are essentially free from dust.

Table 4-8. Characteristics Pertinent to Roads and Airfields

FM 5-35

Major Divisions (1) (2)		Symbol			Name (6) (5)	Value as Subgrade When Not Subject to Frost Action (7)	Value as Subbase When Not Subject to Frost Action (8)	Value as Base When Not Subject to Frost Action (9)	Potential Frost Action (10)	Compressibility and Expansion (11)	Drainage Characteristics (12)	Compaction Equipment (13)	Unit Dry Weight lb per cu ft (14)	Typical Design Values	
		Letter (3)	Hatching (4)	Color (5)										CBR (15)	Subgrade Modulus k lb per cu in. (16)
COARSE- GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Excellent	Good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	125-140	40-80	300-500
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Good	Fair to good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	110-140	30-60	300-500
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Good to excellent	Good	Fair to good	Slight to medium	Very slight	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	125-145	40-60	300-500
						Good	Fair	Poor to not suitable	Slight to medium	Slight	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	115-135	20-30	200-500
		GC		Yellow	Clayey gravels, gravel-sand-clay mixtures	Good	Fair	Poor to not suitable	Slight to medium	Slight	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	130-145	20-40	200-500
	SAND AND SANDY SOILS	SW		Red	Well-graded sands or gravelly sands, little or no fines	Good	Fair to good	Poor	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller	110-130	20-40	200-400
		SP			Poorly graded sands or gravelly sands, little or no fines	Fair to good	Fair	Poor to not suitable	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller	105-135	10-40	150-400
		SM		Yellow	Silty sands, sand-silt mixtures	Fair to good	Fair to good	Poor	Slight to high	Very slight	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	120-135	15-40	150-400
						Fair	Poor to fair	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-130	10-20	100-300
		SC		Yellow	Clayey sands, sand-clay mixtures	Poor to fair	Poor	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-135	5-20	100-300
FINE- GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor to fair	Not suitable	Not suitable	Medium to very high	Slight to medium	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	90-130	15 or less	100-200
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Poor to fair	Not suitable	Not suitable	Medium to high	Medium	Practically impervious	Rubber-tired roller, sheepsfoot roller	90-130	15 or less	50-150
		OL			Organic silts and organic silt-clays of low plasticity	Poor	Not suitable	Not suitable	Medium to high	Medium to high	Poor	Rubber-tired roller, sheepsfoot roller	90-105	5 or less	50-100
	SILTS AND CLAYS LL IS 50 or greater	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable	Not suitable	Medium to very high	High	Fair to poor	Sheepsfoot roller, rubber-tired roller	80-105	10 or less	50-100
		CH			Inorganic clays of high plasticity, fat clays	Poor to fair	Not suitable	Not suitable	Medium	High	Practically impervious	Sheepsfoot roller, rubber-tired roller	90-115	15 or less	50-150
		OH			Organic clays of medium to high plasticity, organic silts	Poor to very poor	Not suitable	Not suitable	Medium	High	Practically impervious	Sheepsfoot roller, rubber-tired roller	80-110	5 or less	25-100
HIGHLY ORGANIC SOILS		Pt		Orange	Peat and other highly organic soils	Not suitable	Not suitable	Not suitable	Slight	Very high	Fair to poor	Compaction not practical	-	-	-

Note:

- Column 3, division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is on basis of Atterberg limits; suffix d (e.g., GMd) will be used when the liquid limit is 25 or less and the plasticity index is 5 or less; the suffix u will be used otherwise.
- In column 13, the equipment listed will usually produce the required densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled. In some instances, several types of equipment are listed because variable soil characteristics within a given soil group may require different equipment. In some instances, a combination of two types may be necessary.
 - Processed base materials and other angular materials. Steel-wheeled and rubber-tired rollers are recommended for hard, angular materials with limited fines or screenings. Rubber-tired equipment is recommended for softer materials subject to degradation.
 - Finishing. Rubber-tired equipment is recommended for rolling during final shaping operations for most soils and processed materials.
 - Equipment size. The following sizes of equipment are necessary to assure the high densities required for airfield construction:
 - Crawler-type tractor -- total weight in excess of 30,000 lb.
 - Rubber-tired equipment -- wheel load in excess of 15,000 lb.
 - Sheepsfoot roller -- unit pressure (on 6- to 12-sq-in. foot) to be in excess of 250 psi and unit pressures as high as 650 psi may be necessary to obtain the required densities for some materials. The area of the feet should be at least 5 per cent of the total peripheral area of the drum, using the diameter measured to the faces of the feet.
- Column 14, unit dry weights are for compacted soil at optimum moisture content for modified AASHTO compaction effort.
- In column 15, the maximum value that can be used in design of airfields is, in some cases, limited by gradation and plasticity requirements.

Table 4-2. Unified Soil Classification System

UNIFIED SOIL CLASSIFICATION (Including Identification and Description)											
Major Divisions		Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights.)	Information Required for Describing Soil	Laboratory Classification Criteria					
1	2	3	4	5	6	7					
Coarse-grained Soils More than half of material is larger than No. 200 sieve size. More than half of material is larger than the smallest particle visible to the naked eye.	Gravels More than half of coarse fraction is larger than No. 4 sieve size (for visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics. Give typical name; indicate approximate percentage of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).	Determine percentage of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows: GW, GP, SW, SP, GM, GC, SM, SC. Borderline cases requiring use of dual symbols. Less than 5% fines More than 5% to 12% fines 5% to 12% fines	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3		Not meeting all gradation requirements for GW	
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			Atterberg limits below "A" line or PI less than 4			Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixture.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below.)			Atterberg limits above "A" line with PI greater than 7			
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below.)			Atterberg limits above "A" line with PI greater than 7			
		Sands More than half of coarse fraction is smaller than No. 4 sieve size (for visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines			Wide range in grain size and substantial amounts of all intermediate particle sizes.	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3		Not meeting all gradation requirements for SW
				SP	Poorly graded sands or gravelly sands, little or no fines			Predominantly one size or a range of sizes with some intermediate sizes missing.	Atterberg limits below "A" line or PI less than 4			Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.			Nonplastic fines or fines with low plasticity (for identification procedures see ML below.)	Atterberg limits above "A" line with PI greater than 7		
				SC	Clayey sands, sand-clay mixtures.			Plastic fines (for identification procedures see CL below.)	Atterberg limits above "A" line with PI greater than 7		
	Fine-grained Soils The No. 200 sieve size is about the smallest particle visible to the naked eye.	Silt and Clays Liquid limit is less than 50	Identification Procedures on Fraction Smaller than No. 40 Sieve Size					For undisturbed soils add information on structure stratification, consistency in undisturbed and remolded states, moisture and drainage conditions. Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML).			
			ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow				None	
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow				Medium	
		Silt and Clays Liquid limit is greater than 50	OL	Organic silts and organic silts clays of low plasticity.	Slight to medium	Slow				Slight	
			MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium				
			CH	Inorganic clays of high plasticity, fat clays	High to very high	None	High				
OH			Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium					
Highly Organic Soils		pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		For laboratory classification of fine-grained soils					

(1) Boundary classifications: Soils possessing characteristics of two groups are designated by combinations of group symbols. For examples GW-GC, well-graded gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U.S. standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS
These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.
Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which clings to a lively consistency and becomes glossy. When the sample is squeezed between the fingers, the water and glass disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

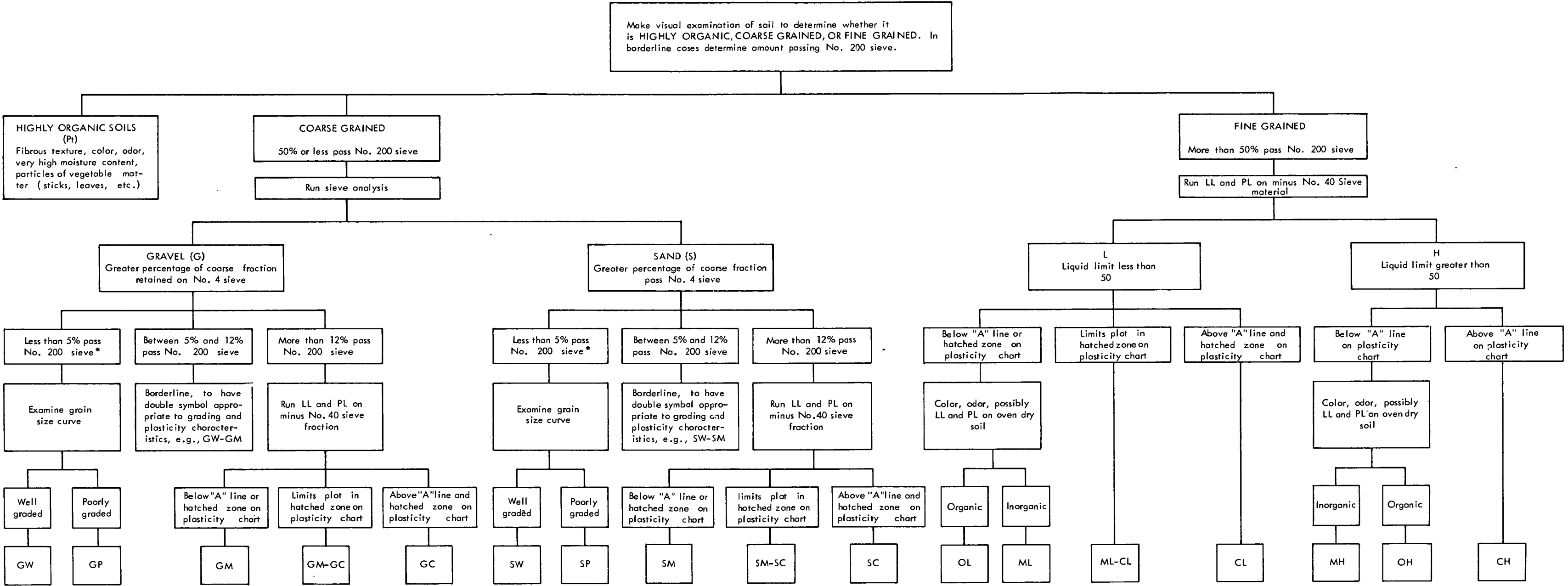
Dry Strength (crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air-drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.
High dry strength is characteristic for clays of the CH group. A typical inorganic silt passes only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (consistency near plastic limit)

After particles larger than the No. 40 sieve size are removed, a specimen of soil about one-half inch in cube size, is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil.
Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line. Highly organic clays have a very weak and spongy feel at the plastic limit.

Figure 4-1. Identification of soils under Unified Soils Classification System.



Note: Sieve sizes are U.S. Standard.

* If fines interfere with free draining properties use double symbol such as GW-GM, etc.

Table 8-3. Minimum Airfield Geometric Requirements, Runway, Taxiway, and Apron

FM 5-35

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
Airfield type	Typical sector	Anticipated service life	Possible using aircraft US type	Runway requirements																							Taxiway requirements							Clear area			Mass apron parking requirements					Warmup apron width ft																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
				Minimum length required, ft	Width ft	Gradients			Shoulders		Clear area		Overrun		Lateral Safety zone		Runway end clear zone			Runway approach zone				Length ft	Width ft	Gradients		Shoulders		Lateral clearance center line runway to near edge of taxiway or fixed obstacle, ft																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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						Width ft	Grade Trans %	Length ft	Width ft	Slope trans %	Width w/o parallel taxiway ft	Length ft	Inner ft	Outer ft	Max Grade %	Length ft	Inner ft	Outer	Glide ratio	Length ft	Width ft	Longitudinal %	Transverse %			Width ft	Grade trans %	Width ft	Grade max trans %		Turn radii ft	Number aircraft	Length ft	Width ft	Grade max trans %	Lateral clearance apron edge to fixed obstacles ft																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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Note. For a reference to airfield geometrics see figs. 8-3 and 8-4.

Runway to be corrected for temperature, altitude, and grade; see nomograph (fig. 8-6).

* Particular aircraft that is critical in load and/or ground run from which area requirements, geometrics, and expedient surfacing requirements were developed.

† Field Army Support Command.

* In 200, instead of 100, ft and no charge in the first 500 at each end.

* Communication Zone.

* 2,500 ft at 10,000 ft from the outer edge of clear zone.

* 8,500 at 10,000 ft from outer edge of clear zone.



